Innovation Activities,Knowledge Sourcing and Perception of Innovation Barriers Evidence from China

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Innovation Activities, Knowledge Sourcing and Perception of Innovation Barriers: Evidence from China

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Abstract

The aim of our research is to explore the effect of firms' innovation activity in China. Our research explores the linkage between firms' knowledge sourcing, innovation output and innovation barrier perception in developing countries. We combine firms' recursive innovation activity based on the research framework of innovation value chain and innovation barrier analysis. Using a database containing innovation panel data obtained from more than 16,000 Chinese firms over the period 2005-2010, we obtained results that show that there are complementary effects between firms' internal knowledge sourcing and other external knowledge sourcing but no substitution effects between any two knowledge sourcings in China. In terms of the knowledge transformation process, we find that in-plant R&D has the most strongly positive and significant effect on the probability of undertaking successful product innovation. Our results based on an estimate of Chinese firms' perception of innovation barriers indicate that profit firms are more likely to perceive government regulation and market information barriers and that Chinese firms perceive government-related innovation barriers as a more important difficulty than other barriers.

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Overview of Section 1

In Chapter 1 we introduce the motivation, research questions and potential contribution of the entire thesis. this chapter is divided into four parts. The first section states the motivation of the research study and the background to the research.The second section outlines the objective of the research. The third section analyzes the potential research gap in existing literatures and indicates the main contribution of this thesis. The fourth section discusses the research questions in the entire thesis and theoretical principles that inform the research issue.

1. Introduction

1.1 Motivation for this research

Innovation is widely regarded as one of the most important factors in today's competitive business environment at both the firm level and the country level. Innovative firms combine their unique resources, skills and competencies to compete in the market. Innovation aims to drive a firm's internal and external capacity, to exploit new ideas and to provide crucial adaptability and flexibility when a firm faces rapidly changing market conditions. Innovation events represent the end of a process of knowledge sourcing and transformation and the beginning of a process of exploitation that may improve a firm's business performance (Roper et al. 2006, 2008; Du et al. 2007). In addition, firms generally encounter many barriers and constraints as they innovate, and this may reduce their success rates. A better grasp of innovation barriers will lead to a deeper understanding of firm-level innovation activities and innovation policy priorities. Therefore, firms' perceptions of innovation barriers and reactions to them are very relevant to their innovation success (Iammarino et al. 2009, Holzl and Janger 2014).

Previous literatures also indicates that there is underlying difference existing between the effect of firms' innovation activities in developed countries and that of firms' innovation activities in developing countries. Developing countries' government

always tends to play a much more important role in individual firms' innovation (Liu and White 2001). The governments of some ambitious and rapid-growth developing countries, such as China, tend to encourage domestic firms to innovate and compete with firms in developed countries. These government innovation support mechanisms have an impact on individual firms' activities. Over the past two decades, the Chinese government has continued to implement policies that encourage R&D cooperation between universities and local enterprises, which supports the idea that governments play a much more important role in local firms' innovation activities in developing countries than in developed countries because of their different national positioning strategies and innovation mechanisms (Sun and Du 2010). In this study, our result also shows that innovative Chinese firms rank government-controlled universities and research institutions as the most important sources of external knowledge. In addition, even privately owned innovation firms in China perceive government-related innovation barriers as the most relevant barriers.

Since the knowledge sourcing, innovative behaviours and innovative mechanisms of enterprises in developing countries differ considerably from those of enterprises in developed countries, innovation is an appropriate way for developing economies to catch up with developed economies (Crespi and Zuniga 2012). It is believed that, in today's unique market environment, Chinese firms innovate not only to survive and remain profitable in existing markets but also to outperform competitors and to obtain a comparative advantage in future international markets (Sun and Du 2010). Although numerous studies have analysed the relationship between knowledge sourcing, innovation activities, and perceived innovation barriers in developed countries (Roper et al. 2008 in Ireland, Ganotakis and Love 2012 in the UK, Love et al. 2012 in Northern Ireland, Lin 2002 in Canada, D'Este et al. 2012 in the UK, Holzl and Janger 2014 in Europe), we find that there is little empirical literature that analyses this innovative loop in export-oriented developing countries. This lack of literature is mainly because few large-sample-based and high-quality innovation panel data surveys have been conducted in developing countries. Therefore, we suggest that further research on how Chinese firms use their resources and competencies to obtain

innovation success and how they perceive and overcome innovation barriers is needed.

1.2 Statement of Research Purpose

Our research aims to explore the linkage between firm's knowledge sourcing, innovation output and innovation barrier perception in developing countries. Our research framework provides more a comprehensive view of firms' innovation environments and innovation behaviour differences between developed and developing countries. We are also interested in analysing how, under China's unique and transitional business environment and export-orientated policy,

1.3 Research Gap and Main Contribution

In this thesis, we will fill in the following existing research gaps. First, previous literatures indicates that the business, economic, and policy environments that innovation firms face in developing countries generally diverge from those that are found in developed countries (Crespi and Zuniga 2012). Although there have been some researches in analysis of firm's recursive innovation process of knowledge sourcing, transformation and perception of innovation barriers in developed countries, there has rarely studied its effects in developing countries. Due to the lack of systematic research based on large sample databases, the existing literatures cannot identify the underlying relationship between different knowledge sourcing and the key determinants of innovation success for exporting-oriented countries' firms.

Second, previous studies have regarded knowledge-related barriers as one of the most important obstacles to innovation (Baldwin and Lin 2002, Hölzl and Janger 2014). This problem is suggested to arise when knowledge transfer is imperfect. However, the existing literature on innovation barriers does not consider the systemic relationship between firms' knowledge absorptive capacity and their perception of knowledge-related barriers. Therefore, how internal capacity influences potential

knowledge barriers to innovation by firms is still unknown.

Third, some previous studies ignore the systematic and consistent effect of government-related factors, both supports and obstacles, on private firms' overall innovation processes. The existing literature regards government-related factors as unimportant or control variables and includes these factors in the analysis of one or two separate knowledge transfer stages rather than considering them as determinant indicators and observing their systematic determinant effects on each step of the knowledge transfer process (Doran and O'Leary 2012).

We believe that our thesis will fill in the above potential research gaps and advance the existing literature by making the following contributions.

First, we describe the linkage between knowledge sourcing, innovation output, and barrier perception based on the knowledge transfer aspect. We first introduce knowledge absorptive capacity in the analysis of firms' perceptions of innovation barriers. Previous studies in this field have ignored the effect of the firm's absorptive capacity on the innovation barrier and have not included the indicators that reflect firms' knowledge storage capabilities (D'Este et al. 2012, Holzl and Janger 2014). We believe that a firm's absorptive capacity is an underlying determinant of the overall innovation process and that it will have a long-term effect on the firm's innovation. Therefore, we indicate that a firm's absorptive capacity would have an effect at each step of the recursive innovation process.

Second, in this study, we highlight the effect of government support on private firms' innovation activities. Previous studies have ignored government influence in developed countries (Iammarino et al. 2009, Doran and O'Leary 2012). This is mainly because the governments of developed countries play a much less important role in private firm's innovation activities and because their support is always provided within a "small government and large market" framework (Liu and White 2003, Eun et al. 2006). In this study, we outline the government's effect in our analysis of the recursive innovation process from knowledge sourcing, transformation, and exploitation to innovation barrier to reflect the actual role of the government in firms' innovation in developing countries. Our results show government's neglecting of

intellectual property protection and lack of government policy support are high ranking innovation barriers when Chinese firms undertake innovation activities. Our results also indicate that even profit firms are more likely to perceive government regulation barriers and that Chinese firms perceive government-related innovation barriers as more of a problem than other barriers.

Third, we extend the use of the recursive innovation process analysis method to one of the largest export-oriented developing countries. We seek for the relationship between different knowledge sourcing in China and identify the key determinant of innovation success for Chinese firms. We find that there exists complementary effect between five common knowledge sourcing. Both key knowledge absorptive capacity and knowledge sourcing will enhance the probability of innovation success.

1.4 Research Question and Focus

Enterprises' innovation processes have been recognized as recursive practices. According to Roper et al. (2008), innovation events represent recursive processes through which firms source the knowledge they need to undertake innovation, transform this knowledge into new products and processes, and then exploit their innovations to generate added value. This process, which may involve feedback loops and external linkages, comprises the IVC.

The IVC has proved a reliable model for analysing the innovation activities of enterprises in developed countries (Doran and O'Leary 2011 in Ireland, Ganotakis and Love 2012 in the UK, Love et al. 2012 in Northern Ireland), but whether the IVC model applies to the business environments of developing countries is unclear. This research first applies the IVC model in the largest and most rapidly growing developing country in the world, i.e., China, asking the following research questions:

1. what is the relationship between different type of knowledge sourcings?
2. What are the key determinants of success in a firm's innovation activities?

In addition, compared with non-innovators, innovators face more challenges and encounter different barriers. Successful innovators need to enhance their ability to

overcome innovation barriers. We focus on the relationship between a firm's perceived barriers and its engagement in innovation and/or the firm's profitability. Therefore, we ask the following research questions:

3. What kind of innovation barriers do firms perceive as the most difficult to overcome when they engage in innovation activities?

4. Are profitable firms more likely to perceive government regulation barriers and market information barriers than they are to perceive financial barriers?

2. Research Framework and Data Collection Methodology

2.1 The Research Question and Project Structure

As we have mentioned above, our thesis will explores the linkage between firms' knowledge sourcing, innovation output and innovation barrier perception in developing countries. We believe that a firm's absorptive capacity is an underlying determinant of the overall innovation process and that it will have a long-term effect on the firm's innovation success and the perception of innovation barrier. Therefore we combine firms' recursive innovation activity based on the research framework of innovation value chain and innovation barrier analysis. This combined research framework has its advantages because innovation value chain integrates knowledge sourcing option, innovation driver and firm productivity enhancement together. Modelling the complete innovation value chain highlights the process of translating knowledge into business value and emphasises the role of skills, capital investment and firms' other resources in the value creation process. And it leads to our analysis of innovation barrier based on firm's absorptive capacity. Therefore, we will contribute the overall linkage between knowledge sourcing, innovation output and barrier perception based on the knowledge transfer aspect. Our result indicates that a firm's absorptive capacity indeed has a significant effect on each step of the recursive innovation process.

More specifically, we address following four questions to construct overall research framework in my thesis:

First, what are the major knowledge sources for innovative firms in China, and what effect does each knowledge sourcing to other ones. More specifically, Do complementary or substituted effect exist between different knowledge sources? We make use of single-equation probit model of each knowledge source to testify complementarity or substitutability effect between Chinese enterprises' knowledge sources. we review research on Chinese enterprises' knowledge sourcing and identify

the interrelationships between different knowledge sources. The key finding is that complementary effects exist between different knowledge sources;

Second, what are the key determinants to firm's innovation activities success during knowledge transformation process? We choose the Innovation Production Functions to examine firms' knowledge transformation activities. We intend to find each knowledge source's contribution to innovation output.

Third, what kinds of innovation barriers do firms perceive when they engage in absorbing knowledge and undertaking innovation activities? We make use of multivariate probit model to analyse how perceptions of innovation barriers are influenced by a firm's engagement in innovation and other firm-level internal resources.

Fourth, are profitable firms more likely to perceive government-related barriers and knowledge-related barriers than they are to perceive financial barriers? Our results suggest that profitable firms in China are more likely to perceive a lack of government policy support, a lack of intellectual property protection, and a lack of information on technology as important barriers rather than financial barrier.

For practitioner, it is always the case to work in and think about the enhancement the innovation success rate and thus occupy larger market in their daily work. Practical considerations also drove the choice to focus on knowledge absorption attributes. As the author's job responsibilities were in the area of innovation management, understanding the underlying attributes to knowledge transfer was a fundamental concern. And there was a desire to develop research outcomes that would lead to practicable applications.

2.2 Database and collection methodology

The data used in this project come from a survey of non-state-owned enterprises conducted by the Chinese government. The survey covers all industrial sectors and includes a wide range of panel data to reflect Chinese firms' innovation behaviours.

All the datasets are tabulated by sector and province. Our dataset covers the annual survey results for the 2005–2010 period. The survey was conducted annually using similar postal survey methodologies with similar questions. Each survey covers innovation and other activities for the firms whose annual revenues were above RMB 200 million in the previous year. Given this dataset, we will be focusing on these ‘‘larger’’ firms. The collected panel data are highly unbalanced, with 17,769 observations over the six-year period.

In order to ensure the reliability and validity of data collection, there are several factors we consider in the research design. The questionnaire used was originally written in Chinese. Academic experts who were familiar with the topic assessed the content validity of each indicator. Before they make use of this questionnaire, they have interviewed some senior managers of enterprise and make sure the indicators can reflect the business reality in China. Based on their feedback, the survey was revised. Another particular attention was paid to affirm the in each firm to fill in questionnaire and reflect the reality. Each firm have appropriate person to fill in the form and the questionnaire have been examined and approved by each firm’s senior managers. Others include the quality of the question wording, piloting, and ensuring that respondents have sufficient time to complete the questions.

2.3 Variable Definition

The definition of variables employed in this thesis is represented in table 1 Table 1 summarizes the definition of variables employed in this study. It contains 30 indicators used to analyse Chinese innovation activity. All the variable definitions are consistent with the survey of non-state-owned enterprises conducted by the Chinese government.

Table 1 Definition of Variables

Variable name	Definition
Innovation Output	Number of patents granted to the firm
Profit	Amount of after-tax profit for the firm
Employment	Total employment in the firm
Firm Age	Number of years since the foundation of the firm
R&D Department	Establishment of an R&D department
Technology Centre	Establishment of a national technology centre
Post-doctoral station	Establishment of a post-doctoral station
Staff with Degree	Percentage of staff with a bachelor's degree or higher
Capital Intensity	Ratio of the firm's total fixed assets to total employment
Government-Granted High-tech Firm	Dummy for the firms' receipt of government-granted high-tech enterprise honors
Government Support Fund	Dummy for the firms' receipt of government innovation support funds
KS_Internal R&D	Dummy for internal R&D being undertaken in the firm
KS_University and Research Institution	Dummy for knowledge sourcing from universities and research institutions
KS_Competitor	Dummy for knowledge sourcing from competitors
KS_M&A	Dummy for knowledge sourcing from mergers and acquisitions
KS_Joint Venture	Dummy for knowledge sourcing from joint ventures
IB_policy support	Dummy for innovation barrier from lack of policy support
IB_research cooperation difficulty	Dummy for innovation barrier from difficulty in cooperation with universities and research institutions

IB_ intellectual property protection	Dummy for innovation barrier from lack of intellectual property protection
IB_high-tech market	Dummy for innovation barrier from immaturity of the high-technology market
IB_management ability	Dummy for innovation barrier from lack of innovative management ability and experience
IB_innovation fund	Dummy for innovation barrier from shortage of innovation funds
IB_reserve of talents	Dummy for innovation barrier from lack of reserve of innovative talent
IB_incentive mechanism	Dummy for innovation barrier from incentive mechanism problems

3. The Knowledge Sourcing Effect on Chinese Firms' Innovation Activities (Project 1)

3.1 Introduction

Innovation is regarded as a commercial application of internal or external knowledge. Firms are organizations that combine their unique resources, skills and competencies to compete in the market. Innovation provides crucial adaptability and flexibility when firms face rapidly changing market conditions (Dess and Picken 2000, Love et al. 2011). Previous research has documented various types of knowledge sources that are used in innovation activities both in the US (Wu and Shanley 2009) and in Europe (Finland, Leiponen and Helfat 2010; Germany, Schmidt 2009; Belgium, Cassiman and Veugelers 2002). These knowledge sources mainly include the firm's internal R&D and the employees that undertake this R&D, competitors in the same industry, university and government research laboratories and agencies, joint ventures and alliances and professional and technical societies. Previous studies that examined the

interrelationship between different knowledge sources focused on the internal and external factors that shape enterprises' engagement with different kinds of knowledge sources. However, findings in the existing literature in this field are mixed. These studies find that a firm's internal R&D activities can either complement or substitute for external knowledge sources in developed countries (Pittaway et al. 2004, Veugelers and Cassiman 1999, Love and Roper 2001, 2004). In addition, the ranking of the importance of different knowledge sources is still controversial, and systematic analysis of the knowledge investment process based on large innovation databases in developing countries is lacking. We believe there are two research gaps in this field. First, they can not confirms whether it exist substitution or complementary effect between different knowledge sourcing in developing country. On one hand, Laursen and Salter (2006) find that a substitution effect exists between internal R&D and the openness of external knowledge sources. On the other hand, Cassiman and Veugelers (2006) found that in-house R&D and external knowledge acquisition are complementary with respect to their impact on innovative performance. Second, previous studies have consistently ignored the effect of government-related support factors on private firms' knowledge acquisition. The existing literature on developed countries always regards government-related factors as unimportant variables rather than considering them as determinant indicators and observing their significant effects on each step of the innovation process.

This project contributes to the literature in the following ways. First, we identify the underlying interrelationship not only between external knowledge sources and internal knowledge sources but also between different external knowledge sources. Our results confirm that complementary effects exist not only between internal R&D and external knowledge sourcing but also between different external knowledge sources; however, no substitutable relationship is observed. Second, we examine the interrelationship between different kinds of knowledge sourcing and enterprises' absorptive capacities and government assistance in China.

In this study, we use a database derived from a survey of private enterprises in China over the 2005–2010 period. The surveyed firms are vibrant, privately owned

enterprises that operate in different industrial sectors of China. These enterprises are an appropriate and interesting group to analyse in terms of the relationship between the emerging non-state-owned economy and firms' innovation activities in China. We intend to identify the typical knowledge sources of Chinese non-state-owned enterprises and to examine the relationship between different knowledge sources. We are interested in investigating whether, under China's unique and transitional business environment, a pattern of complementarity or substitutability can also be observed between Chinese enterprises' knowledge sources.

The remainder of this project is organized into six sections. The second section reviews some related research on the effect of knowledge sourcing and some research on innovation behaviour in China. The third section provides an overview of the conceptual foundations of the IVC model (Roper et al. 2008). The fourth section outlines the database derived from a survey of non-state-owned Chinese enterprises and describes the summary statistics of our data. The fifth section provides an empirical analysis of the complementary or substitutable relationship between different knowledge sources in China. The sixth section outlines the outcomes of our robustness tests. The seventh section concludes the main findings of this project and provides important empirical implications for the innovation activities of Chinese enterprises.

3.2. Theoretical Background

3.2.1 Innovation and Knowledge Sourcing

Given the inherent risk of innovation, firms generally prefer to enhance their opportunities of success by pursuing multiple knowledge sources. **Previous literatures prove that multiple knowledge sourcing have many advantages for innovation firms.** Individual firms seldom complete innovation activities independently because the internal technical capabilities of a single firm are

insufficient to address the challenges of the global market (Jaider et al. 2009). Studies in this field also suggest that the search for new product ideas, new forms of organization, and novel solutions to existing problems leads firms to cross boundaries and to explore the capacities of other firms or organizations. March (1991) suggested that wider and more diverse search strategies will help firms access new opportunities and enable them to develop new organizational competences based on the integration of different knowledge sources.

Since it is proven that firms will benefit from different knowledge sourcing, many empirical studies have indicated that more resource are inputted in internl and external knowledge acquisition. The most important knowledge source is internal R&D. According to the studies of Howells (1999) and Bonte (2003), business expenses related to external R&D in the UK and Germany, respectively, doubled during the 1990s. Moreover, the increasing amount of inter-firm cooperation provides a clear indication of the regular use of external knowledge sources. Hagedoorn (2002) also showed that the number of recorded inter-firm R&D partnerships increased from ten to more than six hundred between the 1960s and the 1990s. Howells et al. (2003) explain that the rapid expansion of external knowledge source usage is primarily a result of the increasingly complex and interdisciplinary nature of the R&D process as well as the shorter technology life cycles and the development of a technology knowledge market.

In addition, researchers also evaluate the effect and efficiency of different knowledge sourcing besides internal R&D. The most significant external knowledge sourcing is university and research institution. Allesch et al. (1988) have studied the innovative contact between universities and firms. Detailed information about the different types of university–industry cooperation has been collected and analysed in this survey. The analysis of Fritsch and Schwirten (1998) of the cooperation between research institutions and firms in Germany shows that 74% of universities and 91% of contract research institutions have relationships with industry. Moreover, it suggests that approximately 34% of the firms have relationships with scientific researchers. Kaufmann and Todtling (2001) found that, on the one hand, advanced innovators are

more likely to cooperate with universities and to do so more frequently. In addition, they are more likely to collaborate with innovation partners that are associated with customers and suppliers. On the other hand, incremental innovators generally seek out university knowledge sources as well as other types of knowledge sources. Meyer-Krahmer and Schmoch (1998) indicate a "two-way bridge" of knowledge transfer from public research institutions to industry firms. They conducted a survey of the cooperative innovation behaviours of German universities. They found that the knowledge exchange occurs in both directions when universities cooperate with industry firms.

In addition, researchers also investigate the relationship between internal and external knowledge sourcing to analyse an innovator's choice between external knowledge sourcing and internal R&D (Veugelers and Cassiman, 1999; Beneito, 2003). A traditional way of analysing this choice comes from transaction cost theory. For example, Williamson (1985) suggested that, because of asset specificity, uncertainty and opportunistic behaviour, transactions that take place within the firm are more efficient and hierarchical than transactions in the market. Using the concepts surrounding the market and hierarchy, several studies have analysed the advantages and disadvantages of innovation outsourcing and in-house R&D. This field has produced two opposing suggestions. On the one hand, external knowledge sourcing and internal R&D are represented as substitutes; as such, in considering costs and risks, firms will choose a make strategy or a buy strategy. Firms thus must manage internal and external innovation strategies and decide which technologies to develop in-house and which to source externally. On the other hand, external knowledge has been suggested as a complement rather than a substitute for internal R&D. The resource-based approach emphasizes that competency development requires a firm to have an explicit policy regarding the use of external knowledge sources as an opportunity to learn rather than as a way of minimizing costs (Robins and Wiersema, 1995). Mowery (1983) found a complementary effect between external knowledge sourcing and internal R&D. He has studied the contracting behaviour of major independent R&D laboratories during the 1900–1940 period and has developed a

transaction cost perspective. His results suggested that the demand for external contract R&D was greater when firms possessed the expertise necessary to identify their needs and to utilize external research. In addition, Cohen and Levinthal (1989, 1990) have analysed the complementary attributes of different innovation strategies. They emphasized that a firm's knowledge base will promote the effectiveness and success rate of the transformation of external technology sourcing by providing a means to understand and utilize the information acquired. They indicated that in-house R&D activities not only can incentivize innovation but also can improve the firm's absorptive capacity, which is their ability to identify, assimilate, and exploit the knowledge generated by competitors and extra-industry sources. Many studies examine the relationships between external knowledge sourcing and in-house R&D. For example, Arora and Gambardella (1990, 1994) suggested that firms that conduct more internal R&D have more opportunities, such as equity participation, acquisitions, and contractual and non-contractual agreements, to acquire external technology. Lowe and Taylor (1998) found a similar relationship between the use of in-house R&D and the purchase of technologies through license agreements. Freeman (1991) suggested that firms with R&D departments are more likely to intensively use external knowledge sources. External knowledge acquisition has also been shown to encourage internal R&D activities. Veugelers (1997) illustrates that external sourcing can often stimulate internal R&D activities, especially in firms with R&D departments. Becker and Dietz (2004) indicated that cooperation with external organizations to acquire knowledge will enhance a firm's in-house R&D intensity.

From the literature above, although definitive evidence has shown the importance of the firm's internal knowledge base in helping it identify and acquire external knowledge and the role of externally acquired knowledge in enhancing internal R&D activities, no affirmative conclusion has been reached about the complementarities between internal and external knowledge sources and the impact on firms' innovative performances. Such complementarities are assumed to exist if the implementation of one strategy increases the marginal returns of another (Milgrom and Roberts, 1990).

Few empirical analyses in this field have investigated this topic, and their conclusions are generally ambiguous. Laursen and Salter (2006) found an inverse U-shaped relationship between the number of a firm's external knowledge sources and its innovation performance. Their findings suggested that the breadth of a firm's external search strategies is beneficial only up to a certain level. They also found that internal R&D has a significant negative relationship with external knowledge sources and innovation performance. A substitution effect exists between internal R&D and the openness of external knowledge sources. On the other hand, some studies have also found a complementary effect. Cassiman and Veugelers (2006) found that in-house R&D and external knowledge acquisition are complementary with respect to their impact on innovative performance. They analyse not only complementarities among innovation activities but also the contextual variables that affect these complementarities. They conclude that the extent to which the firm relies more on "basic" types of knowledge sources, such as universities and research institutions, will influence the strength of the complementarity among innovation activities.

More recently, It is observed that literatures pay more attention on interrelationship between knowledge acquisition and innovation behavior. They focus more on the external innovation environment rather than firm's internal factors. Roper et,al (2013) explore the potential for wider benefits from firm's openness in innovation and argue that openness may itself generate positive externalities by enabling improved knowledge diffusion. They suggest that the social benefits of widespread adoption of openness in innovation may be considerably greater than the sum of the achieved private benefits. Love, Roper and Zhou(2016)'s research develop a model incorporating organisational and managerial knowledge learning effects. They found there is positive exporting effects result from knowledge acquired by manager with prior international experience. Innovation also has positive exporting effects with more radical new-to-the-industry innovation most strongly linked to exports. They analyze firm's innovation behavior from a new aspect: management international experience.

Roper and Hewitt-Dundasa(2015) explore the role of existing knowledge stocks and

current knowledge flows in shaping innovation success. Their results emphasize the importance of firms' knowledge search strategies.

3.2.2 Innovation in China

China has experienced a long period of rapid economic growth since the government implemented the "reform and openness" policy in 1978. According to Grossman and Helpman (1990), innovation is a key driving force of sustainable economic growth. Recognizing the important role of factor accumulation and innovation in growth, the Chinese government and stated-owned or private enterprises started to invest many resources into innovation activities to maintain this rapid economic growth. According to Kuo and Yang (2008), the efforts devoted to promoting social and enterprise innovation have contributed to the high-speed economic growth in China that has occurred over the past 30 years.

The steps involved in the transition of the Chinese innovation system are difficult to describe in detail, but they are clearly a part of the economic transition from a central planning framework to a market orientation. Under the traditional planned system, the government controlled all elements of innovation activities – from the arrangement of different knowledge sources to the outcomes of innovation activities. China followed the Soviet Union's model of establishing specialized organizations: technological R&D was conducted by universities and research institutions; manufacturing was conducted by enterprises; and distribution was conducted by distributors. As such, our research results indicate that private enterprises in China rank universities and research institutions as the top external knowledge sources rather than other important knowledge sources (e.g., suppliers and competitors), which are valued in developed countries. The traditional method of commercializing these innovations from stated-controlled universities and research institutions was of low quality. The traditional innovation framework impeded technological development due to its useless incentive structure under the central planning system. It was one of the most

significant impediments when China implemented its market orientation reforms (Liu and White 2001).

Jefferson and Rawski (1995) indicated that, thanks to the introduction of market competition in the Chinese economy, competition and innovation are together like a ladder on which various (stated-owned or private) enterprises occupy different rungs. They also suggest that the fierce competition between individual enterprises will encourage firms to enhance their quality management. Innovators are able to bring higher-quality and marketable products to the market and thereby enhance their market positions.

However, we should note that, during the transition process of the national innovation framework, the Chinese government maintained an important position, leading and providing support for innovation activities. To maintain China's rapid economic growth, the government has paid increasing attention to analysing and boosting innovation. Several important but indirect efforts have focused on innovation. First, the government actively led the reform of China's national innovation system and attempted to create an innovation-friendly business environment.

The Chinese government's R&D investment increased by approximately 20% annually from 1999–2009. The government has implemented a range of policies to enhance innovation performance at both the macro and the micro level. First, it has established the National Natural Science Foundation and has created several country-level competitive research programmes, such as the 863 Programme, to encourage high-tech research. Second, the government has attempted to promote the research and knowledge generation abilities of universities and public research institutions. It has invested ample funding in the country's leading research universities, such as Tsinghua University and Peking University, in an effort to improve their research performance to world-class levels. Another form of government support for innovation came from province-level investments. A variety of universities and research institutions has been included in local governments' substantial investments to develop "world-class universities", while regional governments have ensured that investments in leading universities are matched by

investments in institutions in their regions. Similarly, key public research institutions have also been funded by the government. For example, the Chinese Academy of Sciences accepted an enormous amount of government funding from the "knowledge innovation project" in the late 1990s.

In addition to government support, firms' cooperation and alliances with external partners have been argued to be substitutes for innovation activities in China. Inkpen and Wang (2006) found that cooperation and alliances have direct effects on innovation in China. Li and Gima (2001) found that cooperation has moderating effects on product innovation and the innovation performance of technological R&D. Like other rapid-growth developing countries, industrial technology development has shown that local firms in China have become more efficient and competitive in their use of foreign technologies (Najmabadi and Lall, 1995). Chen and Sun (2000) have shown that Chinese firms have increased their technology imports since the mid-1990s and that local firms and factories have increasingly purchased foreign advanced technologies of their own initiative. On the other hand, due to Chinese firms' sensible adoption of long-term, flexible, relationship-orientated partnership arrangements to enter foreign markets, their cooperation with international partners has become widespread (Luo, 2003).

In addition, since the 1980s, a popular cooperation model has been generated between universities and research institutions and industrial firms in China. Eun et al. (2006) sought to determine the circumstances under which Chinese universities and research institutions create new firms and run their own businesses to enter a real industrial market. As a result, they ultimately found that some basic determinants, including the internal resources of universities, the absorption capacity of industrial firms, the existence of intermediary institutions, and the propensity of universities to pursue economic gains, will urge Chinese firms to take part in the market.

Compared with most developed countries, China's innovation system is too large and complex to be investigated. It differs from developed countries in the following ways: First, the context of an NIS is unique. China's innovation system was constructed as

part of a transition process from a planned to a market-oriented economy, and emphasizes the leading role of the state in its innovation system.Second,the content of an NIS. the aim of NIS in China is building an enterprise-centered technological innovation system with the state spending a large amount to establish labs, R&D centers and other organizations or buildings, rather than focusing on relationships among various innovative actors. Third, Chinese government, rather than enterprise, plays the leading role in the development, restructuring, and performance of China's innovation system

Previous research on innovation and knowledge source management has shown that accurate predictions of innovation success are difficult. Mansfield et al. (1971) claimed that the average probability of successful innovation commercialization was, on average, 37%. Previous research has documented that innovation activities are risky. According to Leiponen and Helfat (2010), two reasons explain why broader knowledge sources will have positive effects on firms' innovation activities. First, under uncertain conditions, firms may be able to increase the likelihood and value of innovation success by adding a wider range of knowledge sources. Second, research on firm innovation through diverse knowledge sources has suggested that firms may benefit from the complementarities among knowledge sources. In this project, we focus on analysing the knowledge source activities of Chinese enterprises. We suggest a positive relationship between different knowledge sources, especially between internal R&D knowledge sources and external sources; we also wonder how each knowledge source affects the others. We study these questions by formulating the following hypothesis:

H1: Chinese firms' knowledge sources have significantly positive relationships with each other.

3.3. Conceptual Foundations

In this project, we identify five different types of knowledge sources: in-house R&D (Shelanski and Klein 1995), universities or public research institutions (Del Barrio-Castro and Garcia-Quevedo 2005), competitors and joint ventures (Hemphill 2003, Link, Paton, and Siegel 2005), and mergers and acquisitions. We summarize the probability that firms will engage in each of the five knowledge sourcing activities as follows:

$$KS^*_{jt} = \beta KS_{kt} + \gamma_0 RI_{jt} + \gamma_1 KUC_{jt} + \gamma_2 GOVT_{jt} + \varepsilon_{jt},$$

$$KS_{jt} = 1 \text{ if } KS^*_{jt} > 0;\ KS_{jt} = 0 \text{ otherwise}$$

KSjit represents the firm's knowledge sourcing activity *j* (or *k)* at time *t*, and *j*, *k* = 1,2,3,4,5. The error term ε_{jt} is assumed to follow a multivariate normal distribution with mean zero and variance-covariance matrix *V*. For any *j*, *KSkt* represents the firm's knowledge sourcing activities besides *KSjt*. If coefficient β is positive, a complementary relationship exists between firms' knowledge sourcing activities; if coefficient β is negative, a substitute relationship exists between firms' knowledge sourcing activities.

In addition to enterprises' knowledge sourcing, we also use independent variables to reflect the strength of their internal resources and government support. These indicators can be categorized into two groups. One group will provide a quantitative indication of the scale of firms' knowledge resources, such as firm age and firm size. The other group will reflect the quality of firms' internal knowledge base, such as human resource quality and the establishment of an R&D department. We introduce these control variables in the following paragraphs.

Firm size is regarded as one of the most important factors for firm innovation. Bertschek and Entorf (1996) studied the effect of firm size on innovation in Germany, France and Belgium, and they found that this relationship may depend on the country studied. They suggested a negative relationship between firm size and innovation activity in Belgium, a U-shaped curve relationship between firm size and innovation

activity in France and Germany, and a bell-shaped curve relationship between firm size and innovation activity in Germany in another year. The effect of firm size on innovation might be influenced by other factors, such as industry conditions and market structure, which may explain this observed difference. This explanation is consistent with the findings of Acs and Audretsch (1987). They suggested that the innovation activities of small and large companies depend on different technological environments. More recently, Veugelers and Cassiman (1999) found that industry characteristics have a significant effect on the relationship between firm size and innovation. Love and Ashcroft (1999) also found that, compared with small plants, large plants have more innovations but fewer innovations per employee. They further confirmed that larger firm size encourages more innovations but a less proportionate share of innovations per employee (up to a limit of 1,200 employees).

Firm age is another determining factor that has an effect on innovation. A positive relationship is suggested between firm age and innovation. The innovations of older firms are found to have more influence than those of younger ones. Sørensen and Stuart (2000) used two high-tech industry data sets to testify to the effects of firm age on innovation activity. They found that, as organizations age, they are more likely to develop innovations. In addition, an organization's competence to generate new innovations appears to improve with age.

Staffing companies with highly educated, technically qualified and experienced personnel are another important determinant of innovation. Wignaraja (1998) suggested that successful firms try their best to attract an adequate stock of technically qualified manpower to absorb new technologies, create and transfer new technological information, support innovation activities, and increase innovative success rates. Hoffman et al. (1998) confirmed that a firm's growth can be constrained if it is unable to recruit high-quality technological employees. On the other hand, Bell (1984) suggested that firms can enhance their human capital stock over time through formal and informal internal staff training and "learning-by-doing" involvement in R&D.

Government support is another important factor in firms' innovation activities. Many studies have investigated publicly funded R&D. They have suggested that government support for a firm's innovation activities either boosts levels of investment or has a positive effect on the firm's organizational capabilities (Buiseret, Cameron, and Georgiou 1995). According to Coombs and Tomlinson (1998), government policies have a significant positive effect on innovation. He found that the financial support granted by governments, professional organizations, and industry-orientated financial institutions encourages firms to innovate. Keizer et al. (2002) found that the most innovative firms have several basic characteristics in common, including their participation in governmental innovation subsidy schemes. They claimed that, if governments want to incentivize firms to become and remain innovative, they should encourage management to implement and maintain innovation-directed policies. Similarly, Romijn and Albaladejo (2002) also argued that public and government innovation support is necessary, especially in promoting young firms and in boosting pre-competitive research on recently established firms.

In line with the literature reviewed above, we include the following indicators in our econometric model. *RIjit* is a group of indicators that reflect firms' knowledge resources. KUCjit is a group of indicators that reflect firms' absorptive capacities. *GOVTjit* is a group of indicators that reflect access to government support for innovation and upgrades.

According to Greece (2005), one econometric issue is that the multivariate probit (MVP) is not an appropriate knowledge sourcing model because the efficiency gains from MVP are reduced when the vectors of independent variables are strongly correlated. Here, the anticipated determinants of each knowledge-sharing activity are similar to the added potential for the simultaneity between knowledge sourcing activities. In addition, in line with similar research using Irish innovation data (Roper et al. 2008), we encounter the same difficulties that arise when using an MVP approach to analyse our innovation survey data in China. Roper (2006) indicates that, in practice, achieving convergence with an MVP estimator will cause some limits on

the degree of simultaneity. This econometric problem is particularly relevant, as we will testify to the complementary or substitutable relationship between simultaneous knowledge sourcing activities in this project. Therefore, similar to the work by Roper et al. (2008), we employ a simpler approach using five single-probit models; each probit equation represents one knowledge-sourcing activity. We agree with the opinion of Roper et al. (2008) that, although this approach will sacrifice some statistical efficiency, it provides substantial gains in terms of the number of observations used and our ability to reflect more fully the relationship between knowledge sourcing activities.

3.4. Data

The data used in this project come from a survey of non-state-owned enterprises conducted by the Chinese government. The survey covers all industrial sectors and includes a wide range of panel data to reflect Chinese firms' innovation behaviours. All the datasets are tabulated by sector and province. Our dataset covers the annual survey results for the 2005–2010 period. The survey was conducted annually using similar postal survey methodologies with similar questions. Each survey covers innovation and other activities for the firms whose annual revenues were above RMB 200 million in the previous year. Given this dataset, we will be focusing on these ''larger'' firms. The collected panel data are highly unbalanced, with 17,769 observations over the six-year period.

In this database, a series of binary variables represent firms' knowledge-sourcing activities. Binary variables denote whether firms have internal R&D or external cooperative innovation partners over the previous year. Our dataset reveals five common knowledge sources: internal R&D, universities and public research institutions, competitors, mergers and acquisitions and joint ventures.

From our database, we observe that the most common form of knowledge sourcing

was internal R&D, as reported by 55.68% of Chinese firms in the survey (Table 2). The survey suggests that universities and public research institutions are the most common external knowledge sources for firm innovation activities in China (23.5%). Competitors (8.54%) are the third most common knowledge sources, followed by mergers and acquisitions (3.40%) and joint ventures (3.51%).

Table 2 Descriptive Statistics (Project 1)

Variable	Obs.	Mean	Std. Dev.	Min	Max
Knowledge Sources					
KS_Internal R&D (0/1)	17,769	0.557	0.497	0	1
KS_University and Research Institution (0/1)	17,769	0.235	0.424	0	1
KS_Competitors (0/1)	17,769	0.085	0.279	0	1
KS_M&A (0/1)	17,769	0.034	0.181	0	1
KS_Joint Venture (0/1)	17,769	0.035	0.184	0	1
Resources					
Firm Age	17,723	14.92	9.42	1	93
Employment	17,762	2,528.892	6,002.43	5	198,576
Absorptive Capacity					
Staff with Degree (%)	15,117	22.645	21.545	0	100
Formal R&D Department (0/1)	17,754	0.639	0.480	0	1
National Technology Center (0/1)	11,886	0.068	0.252	0	1

Post-doctoral Station	17,747	0.091	0.288	0	1
Government Assistance					
Government-Granted High-Tech Firm (0/1)	17,769	0.347	0.476	0	1
Government Support Fund (0/1)	17,769	0.343	0.475	0	1

Table 3 Correlation Coefficients of Variables (Project 1)

	firmage	employee	staffwithdegree	government High-tech	government support	ks_internal R&D	ks_university& reserch institution	ks_competitor	ks_M&A	ks_jointventure	R&D department
firmage	1										
employee	0.113	1									
staffwithdegree	-0.0408	0.0051	1								
government High-tech	0.0595	0.044	0.0531	1							
government support	0.0606	0.0546	-0.0162	0.2919	1						
ks_internal R&D	0.0353	0.0621	-0.0465	0.1851	0.2701	1					
ks_university& reserch institution	0.0388	0.1069	-0.0273	0.1773	0.3023	0.2573	1				
ks_competitor	0.006	-0.0002	-0.0537	-0.0217	0.0117	0.0172	0.0276	1			
ks_M&A	0.0028	0.071	0.0536	0.0525	0.0392	0.05	0.0901	0.0367	1		
ks_jointventure	-0.0005	0.0243	-0.01	0.0398	0.0422	0.0398	0.0825	0.0313	0.1627	1	
R&D department	0.0643	0.0928	-0.0493	0.1256	0.23	0.39	0.16	0.0028	0.05	0.0474	1

Compared with previous studies that have focused on the knowledge sources of enterprises in developed countries, this study shows that internal R&D is also the most common knowledge source in China. However, the different rankings of external knowledge sources for Chinese enterprises are astonishing. In research in the US and European countries, suppliers (backward knowledge sources) commonly rank as the top external knowledge sources, while universities and research institutions (public knowledge sources) are less important (Roper et al. (2008), Doran and O'Leary (2011)).

There are several explanations for this result. First, given the realities of China's market environment, supply chain management plays a much less important role in Chinese enterprises than it does in enterprises in developed countries. Therefore, knowledge source activities and innovative cooperation with suppliers are limited. Second, because of the lack of intellectual property protection, Chinese enterprises seek to cooperate with universities and research institutions rather than with potential competitors in the market. Therefore, intra- or inter-industry knowledge sourcing activities are limited. Another reason for the selection of different knowledge sources might relate to the dataset used. Unlike standard innovation surveys in developed countries, our database's questionnaire only identifies the five knowledge sources listed above, which are the most common sources in China; it provides interviewees with a blank space to write down "other knowledge sources".

We also include absorptive capacity variables, such as indicators for the share of staff with qualifications, the share of staff with a bachelor's degree or higher, and the establishment of a formal R&D department (Love et al. 2008). According to previous research, absorptive capacity can reflect both the quality of a firm's human resources (Freel, 2005) and its organizational characteristics (Finegold and Wagner, 1998). A firm's innovation ability can be enhanced by hiring and reserving a good team of qualified employees. Firms will take advantage of their employees' academic backgrounds and professional experience to drive consistent innovation activities. Table 2 suggests that, on average, 20.97% of the employees of the sample enterprises

have standard qualifications and that 22.64% of these employees have obtained a bachelor's degree or higher. In addition, 63.87% of enterprises have established a formal R&D department.

We include a control variable for firm size (number of employees) as a resource indicator. Some research supports the Schumpeterian hypothesis, i.e., that large firms are more likely than their smaller competitors to take part in innovation activities (Freel, 2003; Reichstein and Salter, 2006). These studies have indicated that, during the innovation process, large firms can benefit from the economies-of-scope effect and the appropriate diversification of R&D; therefore, large firms are inclined to undertake innovation activities. On the other hand, some studies have produced conflicting results. They have argued that small and medium-sized firms are more likely than larger firms to take part in intensive innovation activities. According to Cohen (1995) and Caloghirou et al. (2004), small firms will remain flexible in handling problems during the innovation process, thereby enhancing their chances of successful innovation. Although its actual influence has been hotly debated, firm size has been shown to influence product innovation behaviours. The average number of employees in the sample firms is 2,529; the number of employees ranges dramatically from 5 to nearly 0.2 million employees across different enterprises.

Another resource indicator in this model is firm age. The in-house resource base is believed to influence internal and external knowledge sourcing and innovation. According to Galende and De la Furnte (2003), older firms can have more experience and greater accumulation in long-term innovation processes. In addition, experienced firms seek to employ internal R&D. As shown in table 2, firm age ranges 1 to 93 years; however, the average firm age in our sample is 14.92 years, which is much younger than the firms in many other countries. No private enterprises existed in China until the "market-centred reform" in 1978, which explains this "young" average firm age. Moreover, the modern corporate system was introduced and accepted by Chinese society just after the Chinese government started to "deepen economic system reform" in 1991.

Since Griliches (1995), studies have argued that government support for enterprises' innovation has a positive impact on their innovation activities. Such support not only boosts the level of investment but also benefits enterprises' organizational capabilities (Buisseret et al., 1995). Other studies suggest that government R&D support will drive private firms to invest in additional private R&D and innovation expenditures or innovation outputs. Government support for innovation has not been found to crowd out private R&D (Hall & Maffioli, 2008; Mairesse & Mohnen, 2010). Government certification and support are more significant for enterprises in China. This significant role is peculiar to China's transitional economy because, until recently, it has differed from a market economy and because the government still controls innovation resources (including funds, human resources and university and public research institution outputs). We thus add some control variables to analyse the effect of government funds and government certification on each firm's innovation activities and knowledge sourcing. From Table 2, we conclude that, on average, 47.6% of the enterprises in our sample have been certified as high-tech enterprises by the government and that 34.30% of the enterprise in our sample have received government funds for high-tech development and innovation.

3.5. Empirical Results

In relation to the IVC, this project seeks to examine the interrelationship among firms' different knowledge sources. Table 4 presents a single-equation probit model of each knowledge source. We are interested in knowing whether a pattern of the complementarity or substitutability effect exists between Chinese enterprises' knowledge sources. The main contribution of our research is our identification of the underlying interrelationship between different knowledge sources in China. We are also interested in determining the key indicator of knowledge sourcing behaviour in China. Our results suggest that internal R&D and the most important external

knowledge sources in China produce strongly significant positive coefficients (universities and research institutions and competitors account for 82.26% of the overall external sources in the survey). These results suggest a strong complementarity between Chinese firms' internal knowledge generation and their external knowledge sourcing, which reflects their absorptive capacities. These findings are similar to those of Cassiman and Veugelers (2002), who suggest that firms may experience complementarities between internal and external knowledge sources. Our results also suggest some complementarity effects between different forms of external knowledge sourcing. In other words, firms that undertake one form of external knowledge sourcing are more likely to have other forms of external knowledge sourcing. This phenomenon occurs because firms' innovation activities can benefit from economies of scope when they effectively manage external relationships. They also can benefit from constantly extending their knowledge acquisition networks. The empirical results support our hypothesis and prove that Chinese firms' knowledge sources have significantly positive relationships with each other. Interestingly, we find no significant substitution effect between any two knowledge sources, running somewhat contrary to previous studies, which find substitutable relationships between internal R&D activities and external knowledge sourcing (Schmidt (2005), Love and Roper (2001), Irwin and Klenow, 1996).

Table 4 Knowledge-Sourcing Equations (single-probit model)

This table illustrates the relationship between Chinese firms' knowledge sources as determined using a single-probit model. The model includes five knowledge-sourcing dummy variables (internal R&D, universities and research institutions, competitors, mergers and acquisitions, joint ventures). The regression examines the complementary or substitution effects between various sources of knowledge. P-values at the 10% level, 5% level and 1% level are denoted *,** and ***, respectively.

Dependent Variables	Internal R&D	Universities and Research Institutions	Competitors	M&A	Joint Ventures
Knowledge Sources					
Internal R&D		0.197*** (0.028)	0.089** (0.043)	0.098* (0.051)	0.033 (0.048)
Universities and Research Institutions	0.158*** (0.276)		0.125*** (0.041)	0.289*** (0.044)	0.258*** (0.043)
Competitors	0.126** (0.054)	0.168*** (0.052)		0.258*** (0.079)	0.176** (0.079)
Mergers and Acquisitions	0.139** (0.065)	0.406*** (0.058)	0.321*** (0.081)		0.940*** (0.066)
Joint Ventures	0.238	0.364***	0.205***	0.923***	

	(0.062)	(0.057)	(0.08)	(0.065)	
Resource Indicators					
Firm Age	-0.002 (0.0012)	-0.0003 (0.0012)	0.001 (0.0018)	-0.002 (0.002)	-0.002 (0.002)
Employment	2.3E-06 (0.0002)	1.45E-05*** (0.0001)	-2.54E-06 (3.25E-06)	1.33E-05*** (2.14E-06)	2.08e-06 (2.95e-06)
Absorptive Capacity					
R&D Department	1.21*** (0.276)	0.743*** (0.034)	-0.050 (0.046)	0.061 (0.058)	0.090 (0.055)
Staff with Degree	-0.002*** (0.0005)	-0.002*** (0.0006)	-0.006*** (0.0009)	0.005*** (0.0007)	-0.002** (0.001)
Government Assistance					
Government-Granted High-Tech Firm	0.506*** (0.028)	0.294*** (0.026)	-0.165** (0.043)	0.078* (0.047)	0.032 (0.045)
Government Support Fund	0.422*** (0.028)	0.411*** (0.025)	0.061 (0.042)	-0.015 (0.046)	0.045 (0.045)

Observations	17769	17769	17769	17769	17769
***p < 0.01, **p < 0.05, *p < 0.1.					

In terms of the relationship between internal and external knowledge sourcing activities, our results indicate a significant positive relationship between internal R&D and external sourcing from universities and research institutions, competitors, and mergers and acquisitions. However, there is also a positive but non-significant relationship between internal R&D and less important knowledge sourcing through joint ventures.

We also find strong evidence of the complementarity among different external knowledge sources for Chinese enterprises. Universities and research institutions and other external sources, including competitors, mergers and acquisitions, and joint ventures, are particularly strongly linked because firms' innovation can benefit from economies of scope when they effectively manage external relationships. Firms can also benefit from constantly extending their knowledge acquisition networks. Universities and research institutions are the most important external knowledge sources, accounting for 60.33% of the overall external knowledge sources in the survey. Out results show a strongly significant complementarity between university and research institution sourcing and competitor sourcing. In addition, a strongly significant complementarity effect also exists between university and research institution sourcing and joint venture sourcing. In addition, we find a strong positive relationship between university and research institution sourcing and merger and acquisition sourcing.

In terms of the dependent variable for competitor knowledge sourcing, we conclude that it has a highly significant complementarity with other external knowledge sourcing. It is shown to have a positive and significant relationship with university and research institution sourcing and merger and acquisition sourcing. It is also shown to have a positive and significant relationship with joint venture sourcing.

The dependent variable for merger and acquisition is suggested to have a strongly significant complementarity with joint venture sourcing and a significant positive effect on competitor sourcing and university and research institution sourcing.

The last dependent variable of the probit equation is joint venture knowledge sourcing. It is suggested to have a strongly significant complementarity with merger and acquisition sourcing, university and research institution sourcing, and competitor sourcing.

Absorptive capacity proves to be more important in shaping firms' knowledge sourcing behaviours, although a very different pattern of influences is evident in firms' internal and external knowledge sourcing. One astonishing result from our research is that the share of employees with a bachelor's degree or higher has a strong negative effect not only on external knowledge sourcing, such as university and research institution sourcing, competitor sourcing, and joint venture sourcing, but also on internal R&D sourcing. In contrast, the share of staff with qualifications has a weak positive effect on internal R&D sourcing, university and research institution sourcing, merger and acquisition sourcing and joint venture sourcing. In terms of the other absorptive capacity variable, the establishment of a formal R&D department has a strong positive effect on internal R&D sourcing and the most important external sources: universities and research institutions. It also has a weak positive effect on merger and acquisition sourcing and joint venture sourcing. These findings suggest that the key determinant of firms' absorptive capacities is their R&D capability and that the level of the organizational capabilities in other parts of the firm is much less significant. This result closely reflects the findings of Schmidt (2005) in analysing Germany firms' absorptive capacities. He also finds that internal R&D has a strong effect on a firm's absorptive capacity to learn from external knowledge acquisition; he also finds much weaker effects related to human resources and knowledge sharing routines within the firm.

Government support has been important in previous research in upgrading firms' innovation and wealth-creating capacities (Roper, 1998; Roper, 2001). In the knowledge sourcing model, we thus include two dummy variables – government-certified high-tech firms and government support funds – to indicate the

effect of this assistance on the probability of engaging in knowledge sourcing. Our results suggest that both kinds of government assistance have strong positive effects on internal knowledge sourcing. Both government-certified high-tech firms and government support funds have significant positive effects on the most important external knowledge sources in China: universities and research institutions. We also concluded that government-certified high-tech firms have a significant negative effect on competitor sourcing. Our result is similar to that of Griliches (1995), which indicates that firms that assisted in product development were more likely to participate in internal R&D but less likely to share knowledge and cooperate with external partners.

In terms of firms' resource indicators, our results show an insignificant and weak relationship between firms' knowledge sourcing strategies and their internal resource base (Schmidt, 2005). We find that firm age has a weak negative effect on internal R&D, which supports the claim that new enterprises prefer internal R&D. However, our results provide little support for a positive or negative relationship between other resource indicators and knowledge-sourcing activities. In addition, firm size has no significant impact on firms' choice of internal knowledge sourcing. However, it does have a positive and significant effect on external knowledge sourcing from universities and research institutions and mergers and acquisitions. However, when observing the relationship between other external knowledge sources and firm resources, we find an insignificant relationship between firm size and other external knowledge sources: competitors and joint ventures.

3.6. Robustness

In our model, five binary equations are used to analyse the effects of knowledge sourcing. The available knowledge sources are internal R&D, universities and research institutions, competitors, mergers and acquisitions, and joint ventures. Although MVP has the econometric issue that its efficiency gains are reduced when

the vectors of the independent variables are strongly correlated, we still employ an MVP as a robustness test to jointly estimate several correlated binary outcomes. This provides us another aspect through which to perceive the relationship between different knowledge sources. The MVP allows us to observe systematic correlations between the simultaneous selection of various forms of knowledge sourcing. Such correlations may be due to complementarity (positive correlations) or to substitutability (negative correlations) between different cooperation types. For example, we find that the benefit of sourcing from mergers and acquisitions may be enhanced if the firm simultaneously sources from universities and research institutions. The benefit of competitor sourcing may be reduced if the firm decreases its joint venture sourcing. The multivariate probit model takes these correlations into account.

The empirical results from the multivariate probit estimation are similar to the outcomes from our single-probit model. Table 5 shows strongly significant positive coefficients between internal R&D and other external knowledge sources: universities and research institutions, competitors, and mergers and acquisitions. This finding suggests complementarity between internal knowledge generation and external knowledge sourcing that reflects a firm's absorptive capacity. Our results also show strong evidence of complementarity between different external knowledge sourcing activities. For example, university and research institution sourcing and other external sourcing, including sourcing from competitors, mergers and acquisitions, and joint ventures, are particularly strongly linked. Again, competitor sourcing is shown to have a significant positive relationship with knowledge sourcing from universities and research institutions, mergers and acquisitions, and joint ventures. In addition, merger and acquisition sourcing shows strongly significant complementarity with joint venture sourcing and a significant positive effect on sourcing from competitors and from universities and research institutions. Joint venture knowledge sourcing is suggested to have strongly significant complementarity with sourcing from mergers and acquisitions, universities and research institutions, and competitors.

Table 5 Knowledge-Sourcing Equations (multivariate probit model)

This table illustrates the relationships between Chinese firms' different knowledge sources as determined using a multivariate probit model. The model includes five knowledge-sourcing dummy variables (internal R&D, universities and research institutions, competitors, mergers and acquisitions, joint ventures). This regression examines the complementary or substitution effects between different knowledge sources. The Z-stat is shown at the 10% level, 5% level and 1% level (denoted *,** and ***, respectively).

Dependent Variables	Internal R&D		Universities and Research Institutions		Competitors		M&A		Joint Venture	
Knowledge Sources										
Internal R&D			0.278***		0.126**		0.139*		0.046	
			(0.040)		(0.061)		(0.072)		(0.069)	
Universities and Research Institutions	0.223***				0.177***		0.408***		0.365***	
	(0.039)				(0.058)		(0.062)		(0.061)	
Competitors	0.176**		0.238***				0.365***		0.249**	
	(0.076)		(0.074)				(0.112)		(0.111)	
Mergers and Acquisitions	0.197**		0.574***		0.454***				1.329***	
	(0.092)		(0.083)		(0.114)				(0.093)	

Joint Ventures	0.034 (0.088)	0.515*** (0.081)	0.290*** (0.114)	1.306*** (0.092)	
Resource Indicators					
Firm Age	-0.003 (0.002)	-0.0004 (0.002)	0.002 (0.003)	-0.002 (0.003)	-0.003 (0.003)
Employment	3.25E-06 (0.0003)	2.05E-05*** 0.0003	-3.59E-06 (0.0005)	0.0002*** (0.00003)	2.95e-06 (0.000004)
Absorptive Capacity					
R&D Department	1.705*** (0.039)	1.051*** (0.048)	-0.071 (0.066)	0.086 (0.082)	0.127 (0.078)
Staff with Degree	-0.003*** (0.001)	-0.003*** (0.001)	-0.009*** (0.001)	0.007*** (0.001)	-0.003** (0.001)
Government Assistance					
Government-Granted High-Tech Firm	0.716*** (0.039)	0.415*** (0.037)	-0.234*** (0.061)	0.110* (0.066)	0.046 (0.064)
Government Support	0.597***	0.582***	0.086	-0.021	0.064

Fund	(0.039)		(0.036)		(0.059)		(0.066)		(0.064)	
Observations	17769		17769		17769		17769		17769	
***p < 0.01, **p < 0.05, *p < 0.1.										

In terms of the effect of absorptive capacity and government support, the outcomes from two different estimation methodologies are quite similar. Based on the multivariate probit model, we still find that the share of employees with a bachelor's degree or higher has a strong negative effect not only on external knowledge sources, such as universities and research institutions, competitors, and joint ventures, but also on internal R&D. The establishment of a formal R&D department has a strong positive effect on internal R&D and on the most important external sources, i.e., universities and research institutions, but a weak negative effect on competitor sourcing. Our results also suggest that both kinds of government assistance have a strong positive effect on internal knowledge sourcing. In addition, both government-certified high-tech firms and government support funds have a significant positive effect on external sourcing from universities and research institutions. In terms of resource indicators, we still find that firm age has a weak negative effect on internal R&D, which supports new enterprises' preference for internal R&D sourcing. However, our results provide little support regarding the positive or negative relationships between other resource indicators and knowledge-sourcing activities. In addition, firm size again proves to have no significant impact on firms' selection of internal knowledge sourcing. However, firm size does have a significant positive effect on knowledge sourcing from universities and research institutions and from mergers and acquisitions.

3.7. Conclusion

In this project, based on the first step of the IVC model, we review research on Chinese enterprises' knowledge sourcing and identify the interrelationships between different knowledge sources. The key finding is that complementary effects exist between different knowledge sources; however, no substitute relationship has been observed. More specifically, our results suggest strongly significant positive coefficients between internal R&D and the most important external knowledge

sources in China: universities and research institutions and competitors. Our results also suggest some complementarity between different forms of external knowledge sourcing (e.g., from universities and research institutions, competitors, joint ventures, and mergers and acquisitions), as firms that undertake one form of external knowledge sourcing are more likely to have other types of external knowledge partnerships.

In terms of the other determinant of knowledge sourcing, we found that the establishment of a formal R&D department has a strong positive effect on internal R&D and the most important external sources: universities and research institutions. This finding is consistent with the suggestion that the key determinant of a firm's absorptive capacity is its R&D capability and that the levels of organizational capability in other parts of the firm are much less significant. Meanwhile, the results indicate that both government-certified high-tech firms and government support funds have a strong positive effect on internal knowledge sourcing. Moreover, these two forms of government support have a significant positive effect on sourcing from universities and research institutions. In terms of firm resource indicators, we find that firm age has a weak negative effect on internal R&D, which supports new enterprises' preference for internal R&D sourcing. We also find that firm size has no significant impact on a firm's choice of internal knowledge sourcing. However, firm size does have a significant positive effect on two external knowledge sources: universities and research institutions and mergers and acquisitions.

From an empirical perspective, our research has elucidated the practical arrangement of Chinese enterprises' investments in available knowledge sources. Under China's unique and transitional business environment, both policymakers and managers will find developing appropriate knowledge sourcing strategies for innovation helpful. In relation to policymakers, our findings indicate that government support will have a significant positive effect on firms' knowledge source absorption capacity. Our results show that government support has an especially strong effect on knowledge sourcing from internal R&D and from universities and research institutions. In relation to firm managers, our findings indicate that, because each knowledge source is

complementary to other knowledge sources, firms should pay more attention to the competitive advantage of knowledge sourcing. Internal R&D investment and cooperation with universities and research institutions are the two most effective choices for knowledge sourcing. In addition, if firms want to enhance their knowledge sourcing from internal R&D and their cooperation with universities and research institutions, establishing an R&D department and recruiting an R&D workforce are good starting points. However, if firms want to enhance their knowledge sourcing from competitors, mergers and acquisitions, or joint ventures, establishing an R&D department is unnecessary.

With regard to further research, we have identified the differences between developing and developed countries using the IVC model. Although our analysis of Chinese firms' innovation has illustrated this difference, it only reflects the reality of one single developing country. If we were to collect innovation data and employ the same methodology to analyse the innovation activities of firms in other developing countries, it would be possible to make the IVC model more representative and better supported.

4. Knowledge Transformation in Chinese Firms' Innovation Activities (Project 2)

4.1. Introduction

After our analysis of enterprises' knowledge-sourcing activities, we turn to the process of knowledge transformation and ponder how knowledge sourcing translates into innovation outputs. Knowledge transformation is key processes that enterprises use to convert their invisible "knowledge store" into actual business performance (Roper et,al 2006). According to Nelson and Winter (1982), at a fundamental level, these processes can be regarded as part of a broader Lamarckian evolutionary dynamic whereby product and process technologies are steadily refined – and occasionally transformed – and firms upgrade their innovation capabilities through organizational learning.

Research has recently focused on the relationship between knowledge input and innovation output. Firms' innovation outputs are widely recognized to reflect not only their internally generated knowledge abilities, which are derived from the outcomes of internal R&D, but also their abilities to integrate different types of knowledge that are sourced from external partners (Love et al. 2010, Roper and Arvanitis 2009). We believe there exists following research gaps in this field. Systematic analysis of knowledge transformation based on a large Chinese innovation database is rare and the efficiency ranking of external knowledge sourcing for firms' innovation success is still controversial. Roper et,al (2008) suggested that forward sourcing is the most important external knowledge origination for private firms' innovation success. In contrast, Doran and O'Leary (2012) claimed that supplier sourcing is the most important type of knowledge sourcing. In addition, previous studies have consistently ignored the effect of government-related support factors on private firms' knowledge

transformation and knowledge exploitation processes (Love and Mansury, 2007). The existing literature on developed countries regards government-related factors as unimportant variables rather than considering them as determinant indicators and observing their significant effect on each step of the innovation process.

This project makes the following contributions to the existing literature. First, whereas previous studies are controversial regarding the importance ranking of external knowledge sourcing for innovation success (Roper et ,al 2008 for forward knowledge, Doran and O'Leary 2012 for supplier knowledge), we found that competitor knowledge sourcing, among others, is the most effective sourcing in terms of promoting firms' product innovation success in China. The other three external knowledge sources have little impact on firms' innovation success. Our results show that the importance of external knowledge sourcing is not universal and that developing countries' firms tend to absorb technology knowledge from competitors. Second, we highlight the effect of government support on private firms' knowledge transformation. Previous studies have ignored government influence in developed countries (Doran and O'Leary 2012). This is mainly because in developed countries government plays a much less important role in private firms' innovation activity and their support is always provided within a "small government and large market" framework. We find that both government-certified high-tech firms and government support funds have a significant positive effect on private firms' product innovation output.

The database used in this project is derived from a survey of private enterprises in China over the 2005–2010 period. The surveyed firms are relatively vibrant, privately owned enterprises that operate in different industrial sectors in China. We seek to examine the relationships between Chinese enterprises' knowledge sourcing and innovation output and between Chinese enterprises' innovation output.

The remainder of the project includes the following six sections. The second section reviews some related research. The third section provides an overview of the conceptual foundations based on the notion of the IVC model (Roper et al. 2008). The fourth section outlines the data derived from a survey of non-state-owned enterprises

in China. The fifth section provides an empirical analysis of the relationship between different forms of knowledge sourcing and innovation output in China. The sixth section presents the outcomes of our robustness test. The seventh section presents the main findings of this project and discusses important empirical implications for Chinese enterprises' innovation activities.

4.2. Literature Review

Previous studies have indicates that knowledge sourcing factors are likely to influence enterprises' innovation success. It is suggested that the relationship between innovation and external knowledge sources, such as customers, suppliers, universities, research centres and other actors in a firm's environment, is either positive (Landry et al., 2002, Ritter and Gemünden, 2003 and Souitaris, 2002) or insignificant (Freel, 2000, Freel, 2003, and Love and Roper, 2001) in developed country. These results indicate that an innovation process will not necessarily be linear. A firm's innovation activities appear as part of an evolutionary, non-linear and interactive process between its internal R&D departments and its external knowledge sources (Dosi et al., 1988, Kaufmann and Tödtling, 2001, Kline and Rosenberg, 1986 and Malecki, 1997).Brandenburger and Nalebuff (1996) find that four external knowledge sources are generally employed in a firm's innovation practices, namely, its suppliers, main consumers, retail outlets, and competitors. On the other hand, these external knowledge sources have been shown to enhance a firm's innovative capability (Lundvall, 1992, Chesbrough, 2003 and Chesbrough, 2007). Love and Mansury (2007) suggested that firms' external links with customers can significantly enhance their innovation performance. Similarly, Leiponen (2005) found that completely new services are most often introduced by firms that engage in external knowledge sourcing.

In addition, it is also indicated that a firm's abortive capacity, i.e., its ability to recognize the value of new information, to assimilate knowledge sources, and to apply innovations to commercial ends, will have a significant effect on a firm's innovation

success(Cohen and Levinthal 1990).A firm's absorptive capacity will help innovators evaluate and transform the most recent scientific or technological developments into innovation outputs in a given field (Koch and Strotmann 2008; Love et al. 2010). Firms' internal research capacities and human resources are also important for innovation success. A large and competent internal R&D department is not only a valuable and strategic asset to drive internal innovation but also a strong barrier to prevent potential competitors from entering the same market. According to Teece (1986), firms with extensive R&D capabilities and complementary assets may outperform their rivals. In addition, staffing companies with highly educated, technically qualified, and experienced personnel with diverse backgrounds are found to increase firms' success rates in terms of innovation activities. Wignaraja (1998) indicated that successful firms should try their best to attract an adequate stock of technically qualified employees who can absorb new technologies, create and transfer new technological information, support innovation activities, and increase innovation success rates. Hoffman et al. (1998) confirmed that firms that are unable to recruit high-quality technological employees will be severely constrained.

Researchers also suggest that some firm's internal and external indicator also have effect on the innovation success. Schumpeter (1942) assumed that innovation activities increase more than proportionally with firm size. This concept confirms that larger firms are more likely to benefit from economies of scale in the innovation process. Another explanation (Legge, 2000) is that larger firms may able to access financial capital with greater ease than smaller firms and are thus more likely to innovate successfully.

Market concentration is also regarded as an important factor in enterprises' innovation success. Angalmar (1985) found that market concentration has a significant negative effect on innovation activities in some industries. He claimed that highly concentrated industries reduce the need for new product development. Using the Herfindahl Index as a measure of market competition, Tingvall and Poldahl (2006) estimated the effect of market competition on industrial innovation. They found an inverted U-shaped

relationship between market competition and firm innovation, indicating that the positive effect of market competition on a firm's innovation only exists up to a certain level. By controlling for inter-industry differences in technological opportunities, Geroski (1990) found a significant positive impact of market power on the extent of innovation activity.

More recently, Roper, Love and Bonner(2017) examine how elements of the local knowledge context and firms' own knowledge gathering activities influence their innovation performance. At the level of the firm they confirms that the importance for innovation of investments in R&D and design, the knowledge skill level of firms' workforces. They also find strong evidence to firms' innovation success and external knowledge acquisition both through interactive collaboration and non-interactive contacts such as demonstration effects, copying or reverse engineering.

Roper and Tapinos（2016）research on Green innovation activity.(Green innovation is generally associated with product, process or organizational changes which reduce the environmental burden of firms' operations, including potentially innovation related to energy saving, pollution prevention, waste recycling and reduced toxicity). The results reinforce the relationship between perceived environmental uncertainty and perceived innovation risk and emphasise the importance of macro-uncertainty in shaping firms' willingness to undertake green innovation.

Previous research has shown that product innovation output depends on a firm's intrinsic innovation resources and the appropriate use of these internal and external knowledge sources during the innovation process. In this project, we focus on the process of transforming the enterprise's knowledge sources into product innovation outputs in China. We seek to examine the relationships between Chinese enterprises' knowledge sourcing and innovation output. We hypothesize that an association exists between a firm's efficiency in translating this knowledge into innovations and said firm's characteristics and unique knowledge resources. We study these questions by formulating the following hypothesis:

H: Knowledge sourcing and absorptive capacity are the key determinants of success in Chinese firms' innovation activities.

4.3. Conceptual Foundations

The conceptual framework is based on the concept of the IVC model. We make use of the knowledge production function to test these hypotheses (Geroski 1990; Harris and Trainor 1995). We are interested in confirming that the effectiveness of firms' knowledge transformation activities is influenced not only by firms' different knowledge resources but also by other factors, including the enterprise's characteristics, the strength of its resource base, its absorptive capacity, and government assistance (Griliches 1992; Love and Roper 1999). This suggests the following knowledge production function:

$$Iit = \phi 0KSkit + \phi\ 1RIit + \phi\ 2KUCit + \phi\ 3GOVTit + \varepsilon it$$

I is the innovation output indicator. In this analysis, we use the number of patents as a dependent variable. In previous research, innovation output has always been estimated with the number of patents or the percentage of innovation-related sales. In this project, we use the number of patents to indicate Chinese firms' innovation activities for the following reasons: first, the number of patents is a more objective and reliable indicator than other comparative variables in China because it is granted by the government. According to Chen et al. (2009), the Chinese government enacted its first patent law in 1984, and the aim of this law is to promote innovation activity and to facilitate technology transfer from government-led research to industries. Therefore, the number of patents granted by the Chinese government has been shown to objectively reflect the technological innovation outcome for each enterprise. Second, the number of patents has been widely regarded as an innovation indicator in previous research in developed countries (Griliches 1979). Crepon et al. (1998) estimated French enterprises' innovation activities and introduced the original Crepon–Duguet–Mairesse (CDM) model by using the number of patents as an

innovation output indicator. According to Acs et al. (2002), the number of patents is a fairly reliable measure of innovation output. In addition, Duguet and Lelarge (2006) suggested that the value of patent rights drives more product innovation and that the value of product innovation further incentivizes patenting. On the other hand, using the number of patents as an innovation outcome indicator presents several drawbacks. Sometimes the number of patents might be a biased indicator of a firm's actual innovation, as the innovative expenses and effort involved do not always lead to patented inventions. Moreover, not all patented inventions will result in marketable products. Firms are more likely to patent inventions that demonstrate the potential to be commercially successful (Artz et al. 2010). However, studies have shown a significant positive relationship between the number of patents and the number of product innovations (McMillan et al. 2003). Therefore, we believe that the number of patents is a reliable indicator of innovation success in investigating Chinese firms' innovation activities.

In the knowledge production function model KS_{kit}, k = 1…5 represent knowledge-sourcing indicators. In terms of innovation outputs, we hypothesize that different knowledge sources will have different effects on firms' product innovation activities. We hypothesize that firms' internal knowledge resources will have strong and positive effects on innovation outputs. Therefore, we expect that the coefficient for internal R&D will be positive with regard to firms' development of new innovations (Crepon et al. 1998; Loof and Heshmati 2001, 2002). For the external knowledge sources, we hypothesize that the different routes through which knowledge of different types might influence different aspects of firms' innovation activities and, in turn, their business performance (Joshi and Sharma, 2004 and Roper et al. 2008). More specifically, we identify five of the most common types of knowledge-sourcing activities in the Chinese market: knowledge sourcing from internal R&D (Shelanski and Klein 1995), from universities or public research institutions (Del Barrio-Castro and Garcia-Quevedo 2005), from competitors, from joint ventures (Hemphill 2003; Link, Paton, and Siegel 2005), and from mergers and acquisitions.

RI*jit* is a group of indicators that reflect a firm's resource base. First, firm size is regarded as one of the most important factors for firm innovation. Bertschek and Entorf (1996) studied the effect of size on innovation in Germany, France and Belgium and found that this relationship might be influenced by other factors, such as industry conditions and market structure. Love and Ashcroft (1999) found that large plants generate more innovations but have fewer innovations per employee. Veugelers and Cassiman (1999) indicated that industry characteristics have a significant effect on the association between firm size and firm innovation activities. Therefore, we hypothesize that a significant positive relationship exists between firm size and product innovation in Chinese enterprises, and we will use a robustness test to demonstrate the industry-dependent effect of firm size on innovation success.

We also test the role of experience in the enhancement of a firm's innovation success through learning effects. We include a control variable for firm age in our econometric model. Sørensen and Stuart (2000) used two sets of high-tech industry data and found that firm age is positively related to innovation activities and that a firm's capacity to produce new innovations appears to improve with age. Therefore, we expect to find a positive relationship between firm age and innovation success in Chinese enterprises.

KUC*jit* is a group of indicators that reflect a firm's absorptive capacity, including the share of staff with qualifications and the establishment of a formal R&D department. We believe that a competent internal R&D department is not only a valuable and strategic asset to drive internal innovation but also a strong barrier to prevent potential competitors from entering the same market. Wignaraja (1998) indicated that successful firms should do their best to attract an adequate stock of technically qualified employees to absorb new technologies, create and transfer new technological information, support innovation activities, and increase innovative success rates. Therefore, we include a variable for a firm's absorptive capacity in our econometric model.

GOVT*jit* is a group of indicators that reflect a firm's access to government support for

its innovation activities. We include two kinds of government support in the model: government-certified high-tech firms and government support funds. According to Coombs and Tomlinson (1998), government policies have a significant positive effect on a private firm's innovation. In addition, they showed that financial support from the government encourages private firms to participate in more innovation activities. Keizer et al. (2002) found that the most innovative firms have several basic characteristics in common, including their participation in governmental innovation subsidy schemes. Mairesse and Mohnen (2010) concluded that government R&D support will drive private firms to invest in additional private R&D and innovation expenditures or innovation outputs. In addition, government support innovation funds have not been shown to crowd out private R&D. Therefore, we expect that the coefficients for both government-related indicators in our model will be positive.

Our estimation approach depends largely on our dependent variable's nonnegative number, which ranges from zero to five thousand. A Poisson model is regarded as an appropriate econometric model for analysing innovation because previous research has shown that innovation is characterized as a Poisson random process (Sahal 1974). Silverberg and Verspagen (2003) proposed that a maximum-likelihood approach based on a Poisson distribution is more appropriate for analysing a firm's innovation because innovation data contain many zero and small-integer values. Compared with a basic ordinary least-squares (OLS) framework, Poisson regression has two major advantages. On the one hand, Poisson regression has a flexible error structure. It allows for a variety of other error structures, while OLS regression can only assume a conditional normal error structure. On the other hand, Poisson regression allows the predicted outcomes to be transformed; this can linearize a potentially nonlinear relationship between the dependent variable and the predictors. In Poisson regression, the observed scores can be counts, and the predicted scores are the natural logarithms of the counts (Coxe er.al, 2009).

Because we have chosen Poisson regression, the main econometric issue that we need to consider is the over-dispersion effect. While the standard Poisson model assumes that the conditional mean and variance are equal, the over-dispersion effect indicates

the variance is larger than the mean. The over-dispersion effect may cause larger conditional variances than the corresponding conditional means. Therefore, its standard errors will be larger than the standard errors in the standard Poisson model. According to the analysis of Silverberg and Verspagen (2003), if over-dispersion is not accounted for, the estimates of the standard errors will be too small; the test statistics for the parameter estimates will be too large; significance will be overestimated; and the confidence limits will be too small.

According to Coxe et al. (2009), over-dispersion occurs for two primary reasons. On one hand, over-dispersion may be caused by omission of an important predictor in the model. On the other hand, each count that occurs for an individual may not be an independent event, but the Poisson distribution assumes that it is. We omit a variable for some sample firms, and because a single firm's innovation output (the number of patents) is not absolutely independent in each survey year, we can reasonably suspect over-dispersion in our regression.

To counter the over-dispersion of Poisson regression, we should use the negative binomial model (Long 1997, Gardner et al. 1995). Because the negative binomial model assumes unexplained variability among individuals who have the same predicted values, it is regarded as an appropriate method for resolving the over-dispersion problem. This additional variability is conceptually similar to the inclusion of an error term in a normal linear regression (Coxe et al. 2009). In addition, according to Lambert (1992), a zero-inflation negative binomial model advantageously corrects for excessive zeros. Because our dependent variable has excessive zeros, we believe that a zero-inflation negative binomial model is more appropriate for our research than a standard negative binomial model. In addition, Greene (1994) provided a testing method for determining when to use the standard negative binomial model and when to use the zero-inflated negative binomial model. He introduced Vuong's (1989) test for the selection of non-nested models between a standard model and a zero-inflated model. If $V > 1.96$, a zero-inflated negative binomial model should be chosen; if $V < 1.96$, a standard negative binomial model should be chosen. Following this methodology, we used Vuong's (1989) test for our

models. Our Vuong test result is V = 3.91, which is greater than 1.96, indicating that a zero-inflated negative binomial model is appropriate. Therefore, we use a zero-inflation negative binomial model to analyse the innovation outcomes for Chinese enterprises.

Another potential econometric issue for the innovation production function is selection bias. Selection bias in innovation behaviour analyses generally stems from two sources. First, the group of innovating firms may be self-selecting, which will lead to a bias between the expected values for the parameters of the estimated innovation production function and the data-generating mechanism for the population as a whole. Second, due to the intrinsic bias of sample design, non-response rates, and survey methodology, to some extent, the selected sample may not be representative of the entire population (Roper and Arvanitis). To counter these biases, we do not abandon any surveyed enterprise innovation data, even though some variables are blank. In addition, because our database is derived from a survey of non-state-owned enterprises in China, the sample enterprises are broadly based and nationally representative. Moreover, the non-response rate is quite low.

Unlike previous studies in this field, we use a cross-industry and cross-region database that includes 17,000 enterprises across more than 20 industries. We believe that our results will provide a more comprehensive view of Chinese enterprises' innovation activities than prior studies have. In addition, as a robustness test, we estimate the determinants of innovation success in the manufacturing industry and service industry. Because previous IVC studies only focus on the manufacturing industry or on the service industry (Roper et, al 2008, Love et al. 2010), our work combines manufacturing enterprises and service enterprises in an innovation behaviour analysis. Using the same econometric framework, we attempt to identify the different effects of firms' internal and external resources on their innovation success in these two industries. Doing so provides us with an easy opportunity to compare outcomes and identify intrinsically different innovation attitudes in the manufacturing and service industries in China.

Distinct from most previous studies, we identify four external knowledge sources that

are overwhelmingly employed in China: universities and public research institutions, competitors, mergers and acquisitions and joint ventures. This study contributes to the literature by investigating how these different external knowledge sources affect Chinese firms' innovation success. We also analyse how these different external knowledge sources interact with an enterprise's internal resources and absorptive capacity and the strength of the enterprise's innovative performance. Previous studies have focused on developed countries. We can reasonably assume that the interactions between external knowledge sourcing and enterprises' innovation outcomes differ considerably between developed countries and developing countries. Therefore, the impact of internal capabilities and the use and ranking of external knowledge sources will be different in the context of a rapidly developing China.

4.4. Data

In project 2, we use the same database as in project 1. The data were obtained from the Chinese government's survey of non-state-owned enterprises. The survey covers all industrial sectors in China and includes a wide range of panel data. All databases are tabulated by sector and province. Our dataset covers the annual survey results over the 2005–2010 period. The survey was conducted annually using similar postal survey methodologies and similar questions. Each survey covers innovation activities and other ordinary business activities in firms whose annual revenues were above RMB 200 million in the preceding years. Notably, in using this dataset, we will research these ‘‘larger’’ firms. The resulting panel is highly unbalanced, with 17,769 observations over a six-year period.

In terms of the innovation output indicator, on average, 43.24% of the surveyed enterprises in the sample report that they have innovation output in the survey year. The average number of patents for the whole sample is 18.49. In addition, the number of patents for each firm varies significantly, ranging from 0 to 4,448.

For knowledge-sourcing indicators, our model has binary variables for five common

knowledge sources: in-house R&D, universities and public research institutions, competitors, mergers and acquisitions and joint ventures. As mentioned in project 1, we observe that the most ordinary form of knowledge sourcing was internal R&D, as 55.68% of Chinese firms reported this form of knowledge sourcing in the survey. Data on firms' external knowledge-sourcing activities suggest that universities and public research institutions are the most common external sources in China (23.5%). Competitors (8.54%) are the third most common knowledge sources, followed by mergers and acquisitions (3.4%) and joint ventures (3.51%).

In addition to the direct effects of knowledge sourcing on innovation output, firms' knowledge-sourcing activities may have indirect effects through their complementarity with other knowledge-sourcing activities. As shown in project 1, internal R&D also has a positive indirect effect on innovation through its complementary effect on the probability that firms will engage in other external knowledge sourcing. This indirect effect is the "absorptive capacity" effect envisaged by Cohen and Levinthal (1989, 1990) and Zahra and George (2002). In terms of absorptive capacity variables, we include the share of staff with qualifications, the share of staff with a bachelor's degree or higher, and the establishment of a formal R&D department (Love et al. 2008). A firm that hires and maintains a good team of qualified employees helps enhance its innovation ability. Firms will take advantage of their employees' academic backgrounds and professional experience to drive consistent innovation activities. Staffing companies with highly educated, technically qualified and experienced personnel with diverse backgrounds has been shown to increase their success rates in terms of innovation activities. Wignaraja (1998) indicated that successful firms should do their best to attract an adequate stock of technically qualified employees to absorb new technologies, create and transfer new technological information, support innovation activities, and increase innovative success rates. Hoffman et al. (1998) confirmed that a firm's growth is severely constrained if it cannot recruit high-quality technological employees. Table 2 suggests that, on average, 20.97% of the employees of the enterprises in our sample have standard qualifications, and 22.64% of them have obtained a bachelor's degree or

higher. In addition, the share of enterprises that have established a formal R&D department is 63.87%.

We include a control variable for firm size (the number of employees) as a resources indicator. Some research has shown that large firms are more likely than their smaller competitors to take part in innovation activities (Freel, 2003; Reichstein and Salter, 2006). According to Cohen (1995) and Caloghirou et al. (2004), small firms will maintain flexibility to address problems during innovation process, thereby potentially enhancing the success rate for innovation. In addition, some researchers have found that the association between firm size and innovation is non-linear. Bertschek and Entorf (1996) studied the effect of firm size on innovation in Germany, France and Belgium and suggested a negative relationship between firm size and innovation activities in Belgium, a U-shaped relationship in France and Germany, and a hump-shaped relationship in Germany in another year. Love and Ashcroft (1999) also found that larger firm size promotes more innovations but a less proportionate share of innovations per employee up to a limited number of employees. Although its real influence is controversial, firm size has been confirmed to have an influence on product innovation behaviour. From our database, the average number of employees in the sample firms is 2,529, ranging dramatically from 5 to nearly 0.2 million employees in enterprises across different industries.

Firm age is another resource indicator in this model. A firm's in-house resource base is believed to influence internal and external knowledge sourcing and innovation. According to Galende and De la Furnte (2003), older firms can have more experience and greater accumulation in the long-term innovation process. In addition, experienced firms generally seek to employ internal R&D. Sørensen and Stuart (2000) claimed that older companies' innovations have more of an influence than those of younger companies and that the competence to produce new innovations appears to improve with age. In our research database, the firm age ranges 1 to 93 years, while average firm age in our sample is 14.92 years. We have mentioned that the average firm age in China is much younger than that in many other countries, as no private enterprises existed in China until the government introduced "market-centred reform"

in 1978.

Since Griliches (1995), government innovation support has been believed to have a positive impact on enterprises' innovation activities. According to Coombs and Tomlinson (1998), government policies have a significant positive effect on a private firm's innovation, and the financial support granted by governments will drive private firms to innovate more. Keizer et al. (2002) found that the most innovative firms have several basic characteristics in common. One common characteristic is participation in governmental innovation subsidy schemes, which not only boosts the level of investment but also benefits a firm's organizational capabilities (Buisseret et al., 1995). Other studies have suggested that government R&D support will encourage private firms to invest in additional private R&D and innovation expenditures or innovation outputs. Moreover, government support funds for innovation have not been found to crowd out private R&D (Hall & Maffioli, 2008; Mairesse & Mohnen, 2010). Therefore, we add control variables to reflect government support funds and the government's certification of each enterprise's innovation and technological development. According to our database, 47.6% of the sample firms have been certified as high-tech enterprises by the government, and 34.3% of the sample firms have received technical support funds from the government.

Table 6 Descriptive Statistics (Project 2)

Variable	Obs.	Mean	Std. Dev.	Min	Max
Innovation					
Innvation Output	17,769	18.49	171.12	0	4448
Knowledge Sources					
KS_Internal R&D (0/1)	17,769	0.557	0.497	0	1
KS_University and Research Institution (0/1)	17,769	0.235	0.424	0	1

KS_Competitors (0/1)	17,769	0.085	0.279	0	1
KS_M&A (0/1)	17,769	0.034	0.181	0	1
KS_Joint Venture (0/1)	17,769	0.035	0.184	0	1
Resources					
Firm Age	17,723	14.92	9.42	1	93
Employment	17,762	2,528.892	6,002.43	5	198,576
Absorptive Capacity					
Staff with Degree (%)	15,117	22.645	21.545	0	100
Formal R&D Department (0/1)	17,754	0.639	0.480	0	1
Government Assistance					
Government-Granted High-Tech Firm (0/1)	17,769	0.347	0.476	0	1
Government Support Fund (0/1)	17,769	0.343	0.475	0	1

Table 7 Correlation Coefficients of Variables (Project 2)

	Firmage	employee	staffwithdegree	government High-tech	government support	ks_internal R&D	ks_university& reserch institution	ks_competitor	ks_M&A	ks_jointventure	R&D department
firmage	1										
employee	0.113	1									
staffwithdegree	-0.0408	0.0051	1								
government High-tech	0.0595	0.044	0.0531	1							
government support	0.0606	0.0546	-0.0162	0.2919	1						
ks_internal R&D	0.0353	0.0621	-0.0465	0.1851	0.2701	1					
ks_university& reserch institution	0.0388	0.1069	-0.0273	0.1773	0.3023	0.2573	1				
ks_competitor	0.006	-0.0002	-0.0537	-0.0217	0.0117	0.0172	0.0276	1			
ks_M&A	0.0028	0.071	0.0536	0.0525	0.0392	0.05	0.0901	0.0367	1		
ks_jointventure	-0.0005	0.0243	-0.01	0.0398	0.0422	0.0398	0.0825	0.0313	0.1627	1	
R&D department	0.0643	0.0928	-0.0493	0.1256	0.23	0.39	0.16	0.0028	0.05	0.0474	1

4.5. Empirical Results

The first research objective of this project is to examine firms' knowledge transformation activities. In investigating the extent to which knowledge sourcing is associated with firm-level product innovation performance, our research follows the established practice (Love and Roper, 1999, Love and Roper, 2001 and Freel, 2003) of modelling innovation outputs using a modified knowledge production function. The result is reported in Table 8. We intend to find each knowledge source's contribution to innovation output. We are also interested in other factors' contributions to firms' knowledge transformation activities. The empirical results support our hypothesis and prove that some knowledge sourcing and absorptive capacity are the key determinants of success in Chinese firms' innovation activities. Our results suggest that some knowledge sources have a significant positive impact on firm product innovation but that some other external knowledge sources have a weak and insignificant impact on product innovation. For example, the strongest positive relationship exists between a firm's product innovation outcomes and internal R&D knowledge sourcing. Competitor knowledge sourcing has a significant positive effect on a firm's product innovation outcomes. In addition, we find that firm size has a significant positive effect on innovation output in China. We also find an insignificant negative effect of firm age on product innovation success. Both kinds of government assistance, i.e., government-certified high-tech firms and government support funds, have a significant positive effect on the product innovation output. All the absorptive capacity variables have a significant positive effect on the product innovation success. Internal R&D has the most significant effect on innovation output compared with external knowledge sources, which suggests that internal R&D is the most valuable resource for a Chinese firm's product innovation output. Our results show that enterprises that conduct internal R&D are 62.3% more likely to develop product innovations. Compared with the marginal effects of other knowledge sourcing

indicators, the marginal effects of internal R&D are the highest. Empirically, internal R&D resource input, rather than external knowledge sourcing, is identified as the most effective and efficient method for Chinese enterprises' product innovation success. In addition, combined with the results from project 1, our results are consistent with the findings of Roper et al. (2008), who indicate that internal R&D contributes more to enterprises' innovation success than external knowledge sourcing.

Table 8 Innovation Production Functions for the Whole Sample
This table provides the regression results for innovation production functions for the overall sample. The model includes several groups of independent variables (firms' resource bases, absorptive capacities, government assistance, internal and external knowledge sourcing, innovation incentive methods). The results show the effects of each variable on Chinese firms' product innovation output. The Z-stat is shown at the 10% level, the 5% level and the 1% level (denoted *,** and ***, respectively).

	Product Innovation		
	Coefficient	Std. Err.	z
Resource Indicator			
Firm Age	-0.004	0.017	-2.2
Employment	9.23e-05	4.5e-06	20.51***
Absorptive Capacity			
R&D Department	0.598	0.062	9.65***
Staff with Degree	0.0012	0.001	1.29
Government Assistance			
Government-Granted High-Tech Firm	0.36	0.362	9.93***
Government Support Fund	0.324	0.036	9.05***
Knowledge Sources			
Internal R&D	0.623	0.046	13.49***
Universities and Research Institutions	0.032	0.034	0.94
Competitors	0.150	0.076	1.98*
Mergers and Acquisitions	0.079	0.083	0.94
Joint Ventures	0.091	0.081	1.11

***p < 0.01, **p < 0.05, *p < 0.1.

In terms of external knowledge sourcing, universities and research institutions have no significant relationship with product innovation success, which is consistent with the findings of Roper et al. (2008), who found no direct relationship between public

knowledge sourcing and innovation success. Our results also suggest that competitor knowledge sourcing has a significant positive effect on Chinese firms' product innovation outputs. Competitor knowledge sourcing increases the probability of product innovation by 15% for Chinese enterprises. This empirical result reflects what we have observed in the Chinese market until now. Much product innovation stems from a firm's imitation of domestic and foreign competitors' mature and popular products. For Chinese firms, product innovations derived from competitor knowledge sourcing could clearly lead to quicker market success compared with innovations derived from other external knowledge sourcing. Therefore, unsurprisingly, competitors are the most important external knowledge sources for Chinese firms. We do not find a significant relationship between knowledge sourcing from mergers and acquisitions and product innovation success for Chinese firms. Similarly, no significant relationship exists between joint venture knowledge sourcing and product innovation success.

In terms of absorptive capacity indicators, we found that the establishment of a formal R&D department has the expected significant positive effect on product innovation success, increasing the likelihood of Chinese enterprises' product innovation by 59.8%. This finding is consistent with those of Roper et al. (2008), who claimed that having a formal R&D department provides a significant advantage in terms of product innovation success. We also find that staff with a bachelor's degree or higher have a positive effect on the innovation output, which is consistent with previous claims in this field (Freel, 2005; Michie and Sheehan, 2003; Roper et al. 2008).

Aside from the variables for knowledge sourcing and absorptive capacity, some other indicators are also important for the success of a firm's product innovation, while some indicators are not. Our results suggest that the effect of internal resources on product innovation output is ambiguous. Similar to the empirical results of Roper et al. (2008), we find that firm age has a negative effect on product innovation output. This finding is consistent with the recognized life-cycle phenomenon of an enterprise's attitude change towards innovation in developed countries, which envisages a

concentration of innovation activity to occur in the first few years after a firm is established, followed by declining levels of innovation and increasing product maturity (Atkeson and Kehoe 2005). On the other hand, we find that firm size has a significant positive effect on product innovation output. Larger Chinese firms are thus more likely to engage in innovation activities, which is consistent with the findings in other developing countries (Crespi and Zuniga 2012).

Government support for innovation has also proved important for innovation activities in China. Both government-certified high-tech firms and government support fund have been found to have a significant positive effect on product innovation success. The government's high-tech designation increases Chinese firms' probability of product innovation by 22.4%. Government support funds increase Chinese firms' probability of product innovation by 16.6%.

To summarize, the results of the innovation production functions are consistent with our hypothesis. Internal R&D knowledge sourcing and competitor knowledge sourcing are found to have a significant positive effect on a firm's product innovation success. The establishment of a formal R&D department, a national technology centre, and a post-doctoral station in firms are also significant indicators. In addition, government support has again proved important for Chinese enterprises' innovation activities. Larger firms are more likely to generate innovation outputs in China. We also find that staff with a bachelor's degree or higher have a significant positive effect on the innovation output. Employees with academic degrees are suggested to have an important effect on product innovation success in China.

4.6. Robustness Test

In this project, our results confirm that the effectiveness of the knowledge transformation process is influenced by firms' different knowledge resources and other factors, including their resource base, their absorptive capacity, and government assistance. However, because the literature has traditionally reported this effect in

service industry samples or manufacturing industry samples, the results from our broader sample are less persuasive. To assess the robustness of these findings, we further classify our sample into two industry groups – one for manufacturing and one for services – and attempt to estimate the effects for each group.

For the manufacturing subgroup, table 9 presents the outcomes from the innovation production function for knowledge transformation activities. We find that internal R&D still has the most significant effect on Chinese firms' product innovation success, which is similar to the results for the whole group. For the other external knowledge sources, we cannot find a significant relationship between any external knowledge sources and product innovation success in China.

In addition to internal and external knowledge sourcing variables, our results for the manufacturing subgroup suggests that firm age has no significant effect on a firm's product innovation output. In contrast, we find a significant positive relationship between firm size and product innovation output for manufacturing subgroup, which is consistent with the results from the whole sample. A firm's profitability also has a significant positive effect on its innovation success.

In terms of absorptive capacity indicators, the establishment of a formal R&D department has the expected significant positive effect on firms' product innovation outputs. This significant positive effect is also found for the manufacturing subgroup. The establishment of a national technology centre has a significant positive effect on manufacturing firms' product innovation success. The establishment of a post-doctoral station also has the expected significant positive effect on firms' product innovation success. Government support for a private firm's innovation also proves important in the manufacturing industry. Both government-certified high-tech firms and government support funds prove to have a significant positive effect on firms' product innovation success in this subgroup.

Table 9 Innovation Production Functions for the Manufacturing Industry

This table provides innovation production functions regression results for the manufacturing industry sample. The model includes several groups of independent

variables (the firm's resource base, its absorptive capacity, government assistance, internal and external knowledge sourcing, and innovation incentive methods). The result shows the effect of each variable on Chinese manufacturing firms' product innovation output. The Z-stat is shown at the 10% level, the 5% level and the 1% level (denoted *,**, and ***, respectively).

	Product Innovation		
	Coefficient	Std. Err.	Z
Resource Indicator			
Firm Age	-0.001	0.002	-0.7
Employment	1.78e-04	6.68e-06	26.65***
Absorptive Capacity			
R&D Department	0.213	0.080	2.67***
Staff with Degree	0.006	0.001	5.63***
Government Assistance			
Government-Granted High-Tech Firm	0.183	0.04	4.58***
Government Support Fund	0.255	0.039	6.56***
Knowledge Sources			
Internal R&D	0.465	0.053	8.72***
Universities and Research Institutions	0.061	0.036	1.68*
Competitors	0.083	0.079	1.04
Mergers and Acquisitions	-0.020	0.095	-0.21
Joint Ventures	-0.012	0.087	-0.14

***p < 0.01, **p < 0.05, *p < 0.1.

For the service subgroup, table 10 illustrates the innovation production function outcomes for knowledge transformation activities. Unlike for the whole group and the manufacturing group, we cannot find a significant effect between internal R&D knowledge sourcing and innovation outputs. With regard to external knowledge sources, the outcomes for the service subgroup also differ from those of the whole

group and the manufacturing group. Competitor knowledge sourcing is shown to have a significant negative relationship with product innovation success. We also find a non-significant negative relationship between knowledge sourcing from mergers and acquisitions and from joint ventures.

Table 10 Innovation Production Functions for the Service Industry

This table provides innovation production functions regression results for the service industry sample. The model includes several groups of independent variables (the firm's resource base, its absorptive capacity, government assistance, internal and external knowledge sourcing, and innovation incentive methods). The result shows the effect of each variable on Chinese service firms' product innovation output. The Z-stat is shown at the 10% level, the 5% level and the 1% level (denoted *,** and ***, respectively).

	Product Innovation		
	Coefficient	Std. Err.	z
Resource Indicator			
Firm Age	-0.011	0.012	-0.97
Employment	1.41e-05	1.29e-05	1.1
Absorptive Capacity			
R&D Department	1.844	0.305	6.05***
Staff with Degree	-0.007	0.003	-2.09**
Government Assistance			
Government-Granted High-Tech Firm	0.53	0.231	2.29**
Government Support Fund	0.422	0.225	1.88*
Knowledge Sources			
Internal R&D	0.117	0.275	0.43
Universities and Research Institutions	0.177	0.228	0.78

Competitors	-1.763	0.524	-3.37***
Mergers and Acquisitions	-0.257	0.347	-0.74
Joint Ventures	-0.453	0.537	-0.84

***p < 0.01, **p < 0.05, *p < 0.1.

In addition to the knowledge-sourcing variables, our results for the service subgroup suggest no significant relationship between firm age and product innovation output. On the other hand, we find that firm size has a non-significant positive effect on product innovation output for the service subgroup. In addition, we do not find a significant relationship between firms' profitability and innovation success in the service subgroup.

In terms of absorptive capacity indicators, the establishment of a formal R&D department, a national technology centre and a post-doctoral station has the expected significant positive effect on product innovation success, which is consistent with the results for the whole group and for the manufacturing subgroup. In addition, while we find a significant positive relationship between staff with a bachelor's degree or higher and innovation output for the whole group and for the manufacturing subgroup, we find a non-significant effect for the service subgroup. We conclude that the effect of high-quality human resources is industry dependent.

In addition, government support for innovation also proves important in the service industry. Government-certified high-tech firms prove to have a significant positive effect on product innovation success in this subgroup. However, we also note that the effect of government support funds is not significant for the service subgroup, which is inconsistent with results for the whole group and for the manufacturing subgroup.

4.7. Conclusion

In this project, based on the second and third step in the IVC model, we examine the

knowledge transformation processes of Chinese enterprises. In terms of the knowledge transformation process, the key finding is that a Chinese firm's internal R&D knowledge sourcing has the most strongly positive and significant effect on its product innovation output. In addition, we find that firm size has a significant positive effect on product innovation output in China. Moreover, both kinds of government assistance, i.e., government-certified high-tech firms and government support funds, have a significant positive effect on product innovation output. The establishment of a formal R&D department also has a significant positive effect on product innovation success.

In this project, our findings provide important implications for both policymakers and managers. For policymakers, our findings indicate that government support will have a significant positive effect on firms' innovation success. Recently, governments have extensively implemented programmes to support firms' innovation activities. Our results show that the implementation of these kinds of policies is appropriate.

For managers, the implications of our findings are threefold. First, internal R&D knowledge sourcing has been shown to be the most effective form of sourcing for firms' innovation activities. To achieve more innovation success, managers should invest more resources into developing firms' internal R&D knowledge-sharing mechanisms. They also should attempt to enhance firms' absorptive capacities by recruiting talented personnel and by applying for a national technology centre and a post-doctoral station. Second, managers should use annual salaries or wage increases to incentivize firms' innovation-related workforce. These two incentive methods are more effective than the alternatives, e.g., equity options or managerial ownership.

With regard to further research, we have identified the differences between developing and developed countries using the IVC model. Although our analysis of Chinese firms' innovation illustrates these differences, it only reflects the reality of one developing country. If we were to collect innovation data and employ the same methodology to analyse the innovation activities of firms in other developing countries, it would make the IVC model more representative and better supported.

5. Perceptions of innovation barriers in developing countries (Project 3)

5.1. Introduction

Innovators always face more challenges and experience different obstacles than non-innovators. Successful innovators need to enhance their abilities to resolve financial difficulties, human resource problems, interactive cooperation obstacles, and many other challenges. A better grasp of innovation barriers will lead to a deeper understanding of firm-level innovation activities and innovation policy priorities (Holzl and Janger, 2014). Recent research has focused on the effect of innovation barriers on firms. Two distinct research streams have been promoted in this field. The first stream focuses on the internal and external factors that affect firms' perceptions of innovation barriers. Such research has found that the greater the firm's involvement in some activities or the more they exhibit particular characteristics, the greater importance they will attach to specific innovation barriers. The ranking of such barriers by firms that are involved in innovation activities is quite similar in developed countries. Firms in developed countries generally perceive financial barriers and skill-related barriers as the most important barriers that they encounter when engaging in innovation activities (Arundel, 1997, Mohnen and Rosa, 2002; Baldwin and Lin, 2002; Tourigny and Le, 2004; Galia and Legros, 2004 D'Este et al., 2012 and Holzl and Janger, 2014). This stream of research also analyses a range of innovation-related firm characteristics, finding that some intrinsic characteristics have an effect on firms' perceptions of innovation barriers. The second stream focuses on how firms' innovation outputs are affected by perceived barriers. Previous studies in this field have paid ample attention to whether perceptions of financial barriers can influence a firm's innovation output (Mohen and Roller, 2005; Savignac 2006; and Tiwari et al., 2007).

However, in examining the effects of firms' innovation barriers on their outputs, previous studies have failed to recognize an important aspect. However, in examining the effects of firms' innovation barriers on their outputs, previous studies have failed

to recognize an important aspect. First, many studies have investigated how financial barriers hamper firms' innovation activities. Although previous studies have shown that financial constraints are one of the most important barriers, few studies have studied how profitable firms perceive innovation barriers. Financial difficulties are obvious and universal barriers for innovative firms worldwide. A more interesting question is how, once they have sufficient financial resources and generate ample profits, firms act as innovators and perceive other innovation barriers.

Second, the existing literature has argued that the more a firm is involved in innovation activities, the more likely it is to face innovation barriers. Interestingly, innovative firms' rankings of innovation barriers are country-dependent. In addition, the coefficients for each innovation barrier differ significantly, reflecting that the degree of importance in relation to innovation involvement differs across barriers. For example, Baldwin and Lin (2002) used data from the Canadian manufacturing industry and found that firms are most likely to report information-related barriers. Holzl and Janger (2014) found that innovative firms in European countries are more likely to report financial and skill-related barriers. In previous studies in developed countries, government-related regulation barriers have been perceived as less important than any other barrier. However, to rapidly enhance national economic growth, governments in developing countries always play a much more important role in innovation. We believe that firms in developed and developing countries will have different perceptions of government-related regulation barriers.

This project will contribute to the literature in three ways. First, we research how profitable firms act as innovators and how they perceive and rank innovation barriers. In addition, while most existing research on financial barriers employs qualitative and subjective questionnaires to investigate firms' financial situations, our research introduces objective accounting profitability data to reflect innovative firms' internal financial resources. Second, although numerous studies have investigated innovation barriers in developed countries, we find that the existing empirical literature lacks large sample-based analyses of innovation barriers and firms' innovation activities in developing countries. Considering the significant differences in the innovation

objectives, innovation functions and innovation mechanisms of developed and developing countries, a gap in this field needs to be filled. Chinese firms offer a particularly interesting and significant sample to analyse the relationship between innovation barriers and innovation activities. Over the past three decades, both China's share of GDP in the world market and Chinese firms' innovative abilities have grown dramatically. This unique growth experience provides an ideal sample of firms to investigate the innovation characteristics for rapid-growth economy. In this project, we use a considerable number of panel data from Chinese non-state-owned firms (more than 17,000 firm data from 2005–2010) to undertake an econometric analysis in this field. We believe that this project can help extend the existing literature in this stream of research.

The remainder of this project is organized into six sections. The second section presents a review of some of the related literature. The third section provides an overview of the conceptual foundations for an analysis of innovation barrier effects. The fourth section outlines the data that are derived from a survey of non-state-owned enterprises in China. The fifth section describes our empirical analysis and the results. The sixth section concludes with the main findings of this project and important empirical implications for Chinese enterprises' perceptions of innovation barriers.

5.2. Literature Review and Research Hypothesis

5.2.1 The effects of a firm's innovation involvement on its perceptions of innovation barriers

Two streams of research analyse the effect of barriers on firms that are involved in innovation activities. One of these research streams focuses on the internal and external factors that potentially affect firms' perceptions of innovation barriers (Arundel, 1997; Mohnen and Rosa 2002; Baldwin and Lin, 2002; Tourigny and Le, 2004; Galia and Legros, 2004 and D'Este et al., 2012). Empirical studies have argued

that a firm's innovation involvement plays an important role in its perceptions of some innovation barriers (Galia and Legros, 2004 and D'Este et al., 2012). Galia and Legros (2004) claimed that certain problems are not effectively encountered until firms face these problems. In other words, only innovative firms face innovation problems. As innovative firms constantly undertake innovation activities, they encounter more problems. Most studies in this field have paid attention to the effect of financial barriers. They have analysed the potential effect of perceived innovation obstacles on a firm's innovation output. Previous studies in this field have paid ample attention to whether a firm's innovation output can be influenced by perceived financial barriers (Mohen and Roller, 2005; Savignac 2006; and Tiwari et al., 2007). Using a sample of Canadian manufacturing firms, Baldwin and Lin (2002) examined different perceptions of barriers by innovators and non-innovators and by advanced technology adopters and non-adopters. Their results showed that, compared with non-innovators and advanced technology non-adopters, a larger proportion of innovators and advanced technologies adopters will perceive impediments to their innovation activities. They also found mixed evidence on the influence of foreign ownership. Using R&D intensity as a proxy for a firm's innovation intensity, Mohnen and Rosa (2002) analysed Canadian service firms that were involved in innovation activities over the 1996–1998 period. They found that the most innovation-intensive firms more frequently report innovation obstacles. In addition, Iammarino et al. (2009) found a significant positive relationship between firms' innovation propensities and their perceptions of innovation barriers. As such, Baldwin and Lin (2002) and Tourigny and Le (2004) even concluded that some kinds of innovation barriers should not be seen to prevent innovation or technology adoption; instead, such barriers are an indication of how successful the firm must be to overcome these obstacles. Their studies also suggested that the greater a firm's engagement in innovation activities, the more likely it will be to perceive the importance of some innovation obstacles.

D'Este et al. (2012) divide innovation barriers into two categories: revealed barriers and deterring barriers. Revealed barriers represent the innovation obstacles that increase innovative firms' awareness of relevant difficulties and increase their

consciousness and knowledge of the factors that constrain innovation. Revealed barriers do not prevent firms from engaging in innovation activities or from being successful innovators. Deterring barriers represent real impediments to a firm's innovation activities, and they generally relate to innovation management and industrial organization. Different types of barriers play distinct roles as deterrents that discourage innovation engagement, tout court, or as revealed obstacles that expose the difficulties inherent in the innovation processes of successful innovators.

Holzl and Janger (2014) found that innovative firms in Europe are the most likely to report skill-related and financial barriers. Their results showed that firms in European countries that are close to the technological frontier perceive knowledge barriers as important obstacles. They also showed that firms in countries that are far from the frontier perceive financial barriers as important obstacles.

However, previous research has focused on how a firm's innovation involvement affects its perceptions of innovation barriers in developed or mature economies, i.e., in a "perfect" market environment. Because governments in developing countries seek to rapidly enhance national economic growth and potentially control exclusive innovation resources, their innovation policies will play a much more important role than those in countries with mature economies. In other words, we believe that the ranking of perceived innovation barriers differs between developing and developed countries. Therefore, investigating this effect under China's developing and transitional market phenomenon is worthwhile. In this project, we assess internal and external determinants that affect Chinese firms' perceptions of innovation barriers.

For policymakers in developing countries, knowing what kinds of innovative firms are more likely to encounter barriers is important. Policymakers also seek to know how innovative firms with different characteristics react to such innovation barriers. We study these questions by formulating the following hypothesis:

H: Firms who are involved in innovation activities are more likely to perceive innovation barriers than non-innovators.

5.2.2 The financial constraints that affect a firm's innovation activities

A parallel stream of theoretical literature focuses on the effect of barriers on firms' innovation propensities and innovation intensity. In other words, such research seeks to understand how perceived barriers affect firms' innovation behaviours. Previous research in this field has paid ample attention to whether perceived financial barriers can influence a firm's innovation output (Mohen and Roller, 2005; Savignac 2006; and Tiwari et al., 2007). Such research has shown that financial barriers have a significant negative effect on firms' engagement in innovation activities. Using data from French manufacturing firms, Savignac (2006) showed that financial obstacles significantly reduce the probability of a firm's engagement in innovative projects. Using the Dutch CIS Database, Tiwari et al. (2007) estimated the effect of perceived financial barriers on R&D investment. Their results also showed that financial constraints significantly discourage a firm's R&D investment in innovation. They found a significant deterrent effect of financial barriers on R&D investment. In addition, they also tested the reverse relationship and determined the effect of firms' innovation activities on their perceptions of financial barriers. Their results showed that, after correcting for endogeneity, a firm's innovation activities have a positive effect on the probability that they will perceive financial obstacles as important. Using survey data and financial accounting data from Italian manufacturing firms from 2001 to 2003, Mancusi and Vezzulli (2010) studied the effect of financial barriers on a firm's decision to undertake innovation. They found a significant negative relationship between the probability of undertaking innovation activities and financial constraints. Pellegrino and Savona (2013) analysed the effect of barriers on the translation process –from firms' participation in innovation activities to actual innovative outputs. They sought to assess what most commonly affects firms' rates of innovation failure in this process. They concluded that a lack of commercial demand and the presence of strong competitors are as important as financial obstacles in influencing a firm's choice to discontinue innovation projects.

In addition, several researchers have investigated which firm characteristics are

determinants of financial barriers. Mancusi and Vezzulli (2010) found that both young firms and small firms have more difficulty in obtaining financing. They claimed that younger firms and smaller firms are much more likely to face credit constraints than older firms and larger firms. Hottenrott and Peters (2012) found a significant positive relationship between a firm's higher innovation capabilities and its perceptions of financial barriers, holding the internal availability of funds equal. As such, firms with high innovative capabilities but limited financial resources are more likely than other firms to be constrained. In addition, they found that a firm's cash flow and profit situation have a significant effect on its innovation activities. They claimed that firms with limited internal funds or bad credit ratings will primarily repay debt rather than investing additional cash in innovation projects. Baldwin and Lin (2002) found that smaller firms perceive a lack of financial resources as a decisive barrier more than larger firms do. In addition, larger firms perceive organizational barriers as decisive. Tourigny and Le (2004) found that individual innovation barriers in the same category may play different roles in firms with different characteristics. For example, although both a lack of financial resources and high innovation costs are categorized as financial innovation barriers, their effects on large firms and small firms are different. They found that smaller firms rank high innovation costs as less important constraints and that larger firms rank a lack of financial resources as a less important constraint.

To explain this significant effect, some recent research has argued that the positive relationship between perceptions of financial barriers and innovation activities results from a combination of econometric biases (Savignac, 2008; Mancusi and Vezzulli, 2010; D'Este et al., 2012). Selection bias can occur if the research sample contains firms that do not want to undertake innovation activities. The inclusion of these non-innovators may induce a positive spurious correlation between a firm's innovation activities and its perception of financial barriers. According to D'Este et al. (2012), this econometric bias will cause an underestimation of deterrent barriers and an overestimation of revealed barriers. Previous research has shown that financial barriers have significant effects on innovation activities in many developed countries, such as the US, the UK, and other European countries. However, few studies have

investigated the effect of a firm's profitability on its perceptions of innovation barriers. If firms obtain ample profits and face little to no financing pressure, how they perceive innovation barriers and overcome these difficulties is an interesting topic to consider. We believe that profitable firms in China are likely to suffer from two kinds of difficulties: market information barriers and government regulation barriers. On the one hand, innovative firms always encounter information asymmetry. Anton and Yao (2002) confirmed that firms are reluctant to fully reveal their potential innovation plans to keep competitors from imitating them. When firms undertake innovation activities, they have more information about their probability of success and the expected returns of their projects than other market participants. On the other hand, due to the imperfection and underdevelopment of markets in developing countries, many technology resources are controlled by the government; therefore, regulation policies have more of an effect on firms' innovation, which is totally different from the market reality in developed countries. In this research, we hypothesize that profitable innovative firms in China are likely to suffer from regulation barriers and technology market information barriers. We study these questions by formulating the following hypothesis:

H: Profitable firms are more likely to perceive government regulation barriers and market information barriers than non-profitable firms.

5.3. Conceptual foundations

In this project, our research focus is an analysis of the effect of innovation barriers on Chinese firms. We analyse how perceptions of innovation barriers are influenced by a firm's engagement in innovation and other firm-level internal resources, controlling for various firm and environmental characteristics. Based on an econometric methodology similar to that used by Hölzl and Janger (2014), we thus estimate the following model:

$$\text{Barrier}_i = \delta_0 + \delta_1 \text{RI}_i + \delta_2 \text{INN}_i + \delta_3 \text{PROFIT}_i + \varepsilon_{2i}$$

For the independent variables, RI_i represents a firm's internal resources that influence

innovation activity. In our research, RI indicators include firm age, firm size, the share of management staff, the share of technology staff, the share of staff with a bachelor's degree or higher, and industry sector. INN_i is a dummy variable that reflects whether this firm engages in innovation. $PROFIT_i$ is a variable that reflects this firm's profit in given year.

For the dependent variables, we use a questionnaire that asks Chinese firms whether they have experienced innovation barriers in the survey year. The community innovation survey (CIS) identifies several main groups of innovation barriers, e.g., cost factors, knowledge factors and regulation factors. Based on the CIS questionnaire framework and our research objective, we consider the following eight innovation barriers in China:

(1) A lack of government policy support

(2) A lack of innovation partners

(3) A lack of intellectual property protection

(4) A lack of information on technology

(5) A lack of management skills

(6) Financial barriers to innovation

(7) A lack of qualified innovation personnel

(8) A lack of innovation incentive mechanisms

The first and third obstacles are regulation barriers; the sixth obstacle is a cost barrier; and the other five obstacles are knowledge barriers.

In the questionnaire, sample firms must report whether they perceive innovation barriers as important. They are allowed to simultaneously choose several barriers. Using results from our survey, we construct a binary dependent variable to reflect innovation barriers. The variable takes a value of 1 if the firm considers the barrier important. The variable takes a value of 0 if the firm does not consider the barrier important.

We introduce a firm's engagement in innovation activities as an independent variable. In the questionnaire, firms must report whether they have introduced at least one

product innovation in the survey year, which serves as a dummy variable for the firm's innovation engagement indicators. Previous research has indicated a non-linear relationship between a firm's innovation involvement and different barriers (P. D'Este et al. 2012). Iammarino et al. (2009) found that the degree of importance of innovation involvement differs across barriers. In this research, we hypothesize that, if a developing country's firms are involved in innovation activities, they will perceive government-related innovation barriers as more important than other barriers.

The other independent variable is a firm's profitability. Previous studies have suggested that equity finance is the best method for providing financial support to innovative firms. Using a database from 38 countries, Kim and Weisbach (2008) suggested that equity finance plays a significantly important role in helping firms raise the requisite capital. They also found that this benefit is stronger for innovation investments than for other fixed investments. We believe that profitable firms in developing countries are less likely to encounter debt-related financial problems and are more likely to attract equity investments. Therefore, profitable firms will perceive information barriers and government regulation barriers, rather than financial barriers, as the most important obstacles.

Similar to the control variables in project 1 and project 2, we use a number of variables to control some firm and sector characteristics that have been shown to have effect on firms' perception of innovation barriers.

First, we include a control variable for firm size (the number of employees) as a resource indicator. Firm size is widely regarded as one of the most important factors in explaining firms' innovation behaviours (Cohen and Klepper, 1996). Because larger firms are able to use various internal and external resources to support innovation projects, we expect that larger firms will be less likely to perceive innovation barriers. Previous studies by Canepa and Stoneman (2007), Mohnen and Röller (2005) and Hölzl and Janger (2014) found that firm size has a significant effect on innovation barriers.

The other resource indicators in this model include firm age. A firm's in-house

resource base is believed to influence internal and external knowledge sourcing and innovation. According to Galende and De la Fuente (2003), older firms can imply more experience and greater accumulation in the long-term innovation process. In addition, experienced firms tend to employ internal R&D.

In addition, we include some absorptive capacity indicators as control variables, such as the share of staff with qualifications, the share of staff with a bachelor's degree or higher, and the establishment of a formal R&D department (Love et al. 2008).

Previous research has suggested that absorptive capacity may reflect both the quality of a firm's human resources (Freel, 2005) and its organizational characteristics (Finegold and Wagner, 1998). Hiring and maintaining a good team of qualified personnel can help enhance a firm's innovation ability. Firms will take advantage of their employees' academic backgrounds and professional experience to drive consistent innovation activities. In this project, we expect that absorptive capacity will play a very important role in the learning effect of innovative firms. It will also have effect on their perceptions of knowledge barriers.

We also employ exporting activity as a control variable. Exporting firms have been shown to encounter more competitive pressures from the international market; therefore, they are more aware of technological knowledge gaps than their purely domestic competitors (Hölzl and Janger 2014). Ample evidence has shown that, across developed countries, exporters perform better than non-exporters in term of innovation and productivity (Bernard et al. (2003) in the US, Wagner (2002) in Germany, Baldwin and Gu (2003) in Canada, Farinas & Martin-Marcos (2007) in Spain). Iammarino et al. (2009) claimed that multi-national firms are more likely to be research-intensive and to have higher levels of and more variety in their accumulated competence than purely domestic firms, which can reduce the perception of barriers. We introduce indicators that reflect Chinese firms' exporting activities to analyse their effect on these firms' perceptions of innovation barriers. China has emerged as the largest exporting country in three decades and has been widely regarded as the "world's factory". Since the Chinese government started to adopt an "openness and reform" policy and encouraged Chinese firms to export to foreign countries in 1978,

China's exports have increased dramatically. This success is partly because of incredibly high level of trading-related innovation. Therefore, firm-level evidence from China should be studied. We would like to know whether Chinese firms' perceptions of innovation barriers have specific characteristics.

We introduce an industry sector dummy as a control variable. Manufacturing firms are suggested to perceive innovation obstacles because they require external financing and trained employees (Hölzl, and Janger 2014). Canepa and Stoneman (2007) found that firms in industries with higher innovation intensity are more likely to encounter obstacles. Iammarino et al. (2009) found that manufacturing firms and service firms have systematically different perceptions of innovation barriers. They found that service firms rank financial barriers, a lack of skilled personnel, and a lack of information on technology as less important innovation constraints than manufacturing firms do.

Because our innovation barrier-dependent variables are constructed as binary variables, two potentially available econometric approaches can be used to estimate the model: a multivariate probit model (MPM) and a linear probability model (LPM). We employ the multivariate probit model (MPM) instead of the linear probability model (LPM) for our baseline analysis. The MPM generalizes the probit model and is a natural extension of the probit model, which allows the error terms to be freely correlated across equations. We expect that the use of the MPM will allow us to resolve the econometric bias associated with the potential correlation of error terms.

5.4. Data

In this project, we use the same database as in project 1 and project 2. The data are derived from the Chinese government's survey of non-state-owned enterprises. The survey covers all industrial sectors in China and includes a group of panel data. All datasets are organized by sector and province. Our dataset covers the annual survey

results over the 2005–2010 period. The survey was conducted annually using similar postal questionnaire methodologies with similar questions. Each survey covers innovation and other firm-level characteristics for firms whose annual revenues were above RMB 200 million in the preceding years. Because we are using this dataset, we will be studying these ‘‘larger’’ firms. The resulting panel is highly unbalanced with 17,769 observations over a six-year period.

Table 11 presents a descriptive analysis of the innovation barriers. As mentioned above, innovative firms in China perceive eight innovation barriers: a lack of government policy support, a lack of innovation partners, a lack of intellectual property protection, a lack of information on technology, a lack of management skills, financial barriers to innovation, a lack of qualified innovation personnel, and a lack of innovation incentive mechanisms. These barriers are the most important obstacles that innovative firms in China face. According to our database, 51.5% of Chinese firms have a lack of qualified innovation personnel. Thus, more than half of the sample firms claimed that their innovation projects are hindered by a lack of innovative human resources. The second-ranking innovation barrier that Chinese firms report is a lack of innovation partners. In the sample, 25.3% of the firms perceive that they have faced problems in cooperating with universities and research institutions when undertaking innovation projects. The third-ranking innovation barriers that Chinese firms report are financial barriers to innovation. In other words, 23% of the sample firms perceive a shortage of innovation funds in their innovation activities. The fourth-ranking innovation barrier is a lack of government policy support, with 19.8% of the sample firms perceiving it as an innovation obstacle. A lack of information on technology comes next, with 18.4% of sample firms perceiving it as an innovation obstacle. A lack of enterprise management skills (8.54%) is the sixth-ranking innovation barrier. The seventh-ranking innovation barrier is a lack of intellectual property protection, with 11.39% of the sample firms perceiving it as an innovation obstacle, followed by a lack of innovation incentive mechanisms (10.39%).

In terms of the innovation output indicator, on average, 43.24% of the sample firms report that they are undertaking innovation activities in the survey year. In terms of

absorptive capacity variables, on average, 20.97% of the sample firms' employees have technology qualifications, and 22.64% of the sample firms' employees have obtained a bachelor's degree or higher, as shown in Table 11.

In terms of other control variables, the average number of employees in the sample firms is 2,529, and the number of employees ranges dramatically from 5 to nearly 0.2 million employees in enterprises across different industries. The firm age ranges 1 to 93 years, while the average firm age in our sample is 14.92 years. We also include exporting indicators in our analysis. Table 2 shows that 46.6% of the sample firms have untaken exporting activities in the survey year and that the average exporting intensity in the whole sample is 1.8%. The other control variable is the innovation output indicator. We calculate that, on average, 43.24% of the sample firms perceive that they have innovation outputs in the survey year. In addition, we also calculate the average after-tax profit of the whole sample: RMB 98.7 million.

In terms of the industry dummy variable, 60.18% of the sample firms belong to the manufacturing industry, while 16.67% of the sample firms belong to the service industry.

Table 11 Descriptive Statistics (Project 3)

Variable	Obs.	Mean	Std. Dev.	Min	Max
Innovation					
Innovation Output	17,769	18.49	171.12	0	4448
Resources					
Firm Age	17,723	14.92	9.42	1	93
Firm Size	17,762	2,528.892	6,002.43	5	198,576
Profit	17,742	9,865.53	32,579.87	-232,647	1,391,146
Staff with Degree (%)	15,117	22.645	21.545	0	100
Staff of Management (%)	11,305	14.85	12.01	2	100
Staff of Tech	15,309	20.97	17.36	0	100

(%)					
Innovation Barriers					
Policy Support	17,769	0.198	0.398	0	1
Innovation Partner	17,769	0.253	0.435	0	1
Intellectual Property Protection	17,769	0.114	0.318	0	1
information on high-tech	17,769	0.184	0.388	0	1
Management Ability	17,769	0.123	0.328	0	1
Innovation Fund	17,769	0.229	0.420	0	1
Reserve of Talent	17,769	0.513	0.5	0	1
Incentive Mechanism	17,769	0.104	0.305	0	1

Table 12 Correlation Coefficients of Variables (Project 3)

	firmage	profitability	exporting	firmsize	percentage of Manag Staff	percentage of Tech Staff	percentage of Staff with Degree
firmage	1						
profitability	0.0457	1					
exporting	0.0108	0.1116	1				
firmsize	0.1641	0.1559	0.1414	1			
percentage of Manag Staff	0.0154	-0.0092	-0.07	-0.1439	1		
percentage of Tech Staff	0.0376	0.0502	-0.1131	-0.0677	0.277	1	
percentage of Staff with Degree	-0.0582	0.1486	-0.1005	-0.0185	0.2848	0.2357	1
Innovation	-0.0025	0.1164	0.0907	0.1826	-0.0108	-0.0282	0.0152

5.5. Empirical Results and Discussion

Table 13 presents the results of the MPM estimation of eight separate equations for each obstacle evaluated by the full sample of firms. The level of significance and coefficients can be found in table 13. Our empirical result supports the hypothesis that profitable firms are more likely to perceive government regulation barriers and market information barriers than non-profitable firms. Our results suggest that profitable firms in China are more likely to perceive a lack of government policy support, a lack of intellectual property protection, and a lack of information on technology as important barriers. In addition, our empirical result also supports the hypothesis that Firms who are involved in innovation activities are more likely to perceive innovation barriers than non-innovators. The dummy for innovation involvement is systematically significant across all barriers. Chinese firms that undertake innovation activities are more likely to perceive all kinds of barriers. The control variables for firm characteristics also prove to be significantly associated with firms' perceptions of innovation barriers.

For the independent variable of innovation involvement, our study finds that Chinese firms' innovation involvement has a significant positive relationship with most innovation barriers, including a lack of government policy support (31.7%, 1% significant), a lack of innovation partners (21.1%, 1% significant), a lack of intellectual property protection (50.44%, 1% significant), a lack of information on technology (28.04%, 1% significant), financial barriers to innovation (8.86%, 1% significant), a lack of qualified innovation personnel (28.17%, 1% significant), and a lack of innovation incentive mechanisms (22.62%, 1% significant). Our results indicate that a significant positive relationship can be observed for seven barriers. These findings lead to two interpretations. First, Chinese firms that engage in innovation activities tend to perceive more innovation barriers. The positive association between firms' innovation involvement and their perceptions of barriers is

in line with prior empirical research. Second, by comparing the coefficients from different barriers, we find that firms are more likely to perceive a lack of intellectual property protection and a lack of government policy support. This finding implies that, when they undertake innovation activities, most firms in China will face government-related obstacles. Chinese firms' rankings of innovation barriers differ from those of firms in developed countries. We hypothesized that the role of local governments in stimulating private firms' innovation will differ between developing and developing countries, as governments in developing countries play a much more important role in local firms' innovation by providing direct or indirect support. Therefore, firms' perceptions of government-related regulation barriers will be important in developing countries. Our results support this hypothesis. Therefore, the government should make more of an effort with regard to innovation support and intellectual property protection to provide positive incentives that encourage Chinese firms to undertake innovation activities. Moreover, we also find that Chinese firms' innovation involvement has a negative but insignificant relationship with an enterprise's lack of management skills. Therefore, a lack of innovative management experience is not a crucial reason for the failure of innovation in China.

Table 13 Innovation Barrier Regression Results (Multivariate Probit Model)

This table presents the results of the analysis of Chinese firms' perception of innovation barriers obtained employing a multivariate probit model. The model includes eight regular innovation barriers (lack of government policy support, lack of innovation partners, lack of intellectual property protection, lack of information on technology, lack of enterprise management skill, financial barriers to innovation, lack of qualified innovation personnel, and lack of innovation incentive mechanisms). The z-stat is shown at the 10% level, the 5% level and the 1% level (denoted *, ** and ***, respectively).

Dependent Variables	Lack of government policy support	Lack of innovation partners	Lack of intellectual property protection	Lack of information on technology
Firm age	-0.0016 (0.001)	0.003** (0.001)	0.0005 (0.0017)	-0.0029* (0.002)
Profitability	0.07*** (0.025)	0.134*** (0.024)	0.102*** (0.031)	0.1*** (0.027)
Exporting	-0.022 (0.025)	0.1*** (0.03)	0.284*** (0.038)	0.023 (0.033)
Firm size	0.097*** (0.031)	0.1*** (0.03)	0.132*** (0.038)	0.094*** (0.033)
Percentage of management staff	-0.0018 (0.0013)	0.0005 (0.0013)	0.001 (0.0016)	0.0017 (0.0014)
Percentage of technology staff	-0.00016 (0.0009)	-0.0028*** (0.001)	0.0029** (0.001)	-0.0006 (0.001)
Percentage of staff with	0.0058***	0.0009	0.0017**	0.0009

bachelor's degree or above	(0.0008)	(0.0007)	(0.0008)	(0.0007)
Innovation	0.327*** (0.032)	0.211*** (0.03)	0.504*** (0.038)	0.28*** (0.032)
Manufacturing Dummy	0.029 (0.037)	0.073* (0.035)	0.285*** (0.047)	0.093** (0.039)
Service Dummy	-0.184*** (0.054)	-0.395*** (0.055)	0.045 (0.072)	-0.217*** (0.059)

Table 13 Innovation Barrier Regression Results (Multivariate Probit Model) (Continued)

Dependent Variables	Lack of enterprise management skill		Financial barriers to innovation		Lack of qualified innovation personnel		Lack of innovation incentive mechanism	
Variable	Coefficient	z-stat	Coefficient	z-stat	Coefficient	z-stat	Coefficient	z-stat
Firm age	-0.0017 (0.002)		-0.0005 (0.001)		0.003** (0.001)		0.0046*** (0.002)	
Profitability	-0.114*** (0.03)		-0.209*** (0.024)		0.064*** (0.022)		-0.0076 (0.033)	
Exporting	0.018 (0.04)		-0.2*** (0.03)		0.109*** (0.028)		-0.077* (0.041)	
Firm size	-0.049 (0.039)		0.109*** (0.03)		0.109*** (0.027)		0.078* (0.042)	
Percentage of management staff	0.002 (0.002)		-0.003** (0.001)		-0.0006 (0.001)		-0.0012 (0.002)	
Percentage of technology staff	0.0005 (0.001)		0.0008 (0.001)		-0.0013 (0.001)		-0.0001 (0.001)	
Percentage of staff with	-0.006***		0.002***		-0.002***		-0.0034***	

bachelor's degree or above	(0.001)	(0.001)	(0.001)	(0.001)
Innovation	-0.068* (0.039)	0.089*** (0.03)	0.282*** (0.028)	0.226*** (0.041)
Manufacturing Dummy	-0.102** (0.045)	-0.019 (0.035)	0.038 (0.033)	0.051 (0.049)
Service Dummy	-0.196*** (0.066)	-0.418*** (0.05)	-0.42*** (0.045)	-0.226*** (0.078)

For the independent variable of profitability, our results confirm that profitable firms are more likely to perceive government-related barriers and market information barriers as important. Firms perceive a lack of intellectual property protection (10.2%, 1% significant), a lack of information on technology (10%, 1% significant), a lack of innovation partners (13.4%, 1% significant), and a lack of government policy support (7%, 1% significant) as major innovation barriers. On the other hand, profitable firms perceive financial barriers (-20.9%, 1% significant) as less important, which is consistent with our hypothesis. Profitable innovative firms in China are more likely to encounter government regulation barriers and market information asymmetry instead of financial barriers. Our results indicate that profitable Chinese firms have fewer financial barriers when they undertake innovation activities. Profitable firms are more likely to invest in innovation programmes. Interestingly, we find that profitable Chinese firms rank a lack of intellectual property protection and a lack of government policy support as the most important innovation barriers. In addition, we conclude that profitable firms perceive fewer innovation barrier related to management skills because profitable firm have more resources and competencies to recruit qualified managers.

For the control variables, our results show that older Chinese firms tend to encounter more innovation barriers than younger firms. As we report in table 13, we find that firm age has a significant positive relationship with the following barriers: a lack of innovation partners, a lack of qualified innovation personnel, and a lack of innovation incentive mechanisms. In addition, we do not find a significant difference between old and young firms for some innovation barriers. (e.g., lack of government policy support, lack of intellectual property protection, lack of enterprise management skills, or financial barriers to innovation). Our results confirm that younger Chinese firms have more flexibility than older firms in developing innovation incentive mechanisms and obtaining qualified innovative personnel and appropriate partnerships. In addition, we find a significant positive relationship between firm size and most innovation barriers. Larger firms tend to perceive more innovation barriers, even financial barriers. Our results are similar to those of most empirical research and confirm that

the relative strength of small firms lies in their innovation flexibility (Iammarino et al. (2009)). By comparing the coefficient results, we find that firm size plays the most important role in terms of financial barriers (13.2%). The sample firms regard a lack of innovation partners (10.9%) and a lack of qualified innovation personnel (10.9%) as the second-ranking innovation barriers, followed by a lack of government policy support (9.7%).

In terms of the exporting control variable, our study analyses the relationship between firms' involvement in exporting and their perceptions of innovation barriers. On the one hand, we find that Chinese firms' involvement in exporting has a significant negative relationship with financial barriers to innovation. On the other hand, we also find that Chinese firms' involvement in exporting has a significant positive relationship with a lack of innovation partners, a lack of intellectual property protection, and a lack of qualified innovation personnel. In other words, Chinese exporters will perceive fewer financial innovation barriers than non-exporting firms when they undertake innovation activities because the former generally face fierce competition in the international market and have diversified capital resources to support innovation activities. In addition, the significant positive effect on some barriers indicates that Chinese firms that simultaneously undertake innovation and exporting will most likely face intellectual property protection problems in the domestic innovation market. A lack of appropriate innovation staff and innovation partners are other important obstacles.

In considering the human resource factors, we analyse the innovation barrier effects of three variables: the share of management staff, the share of technology staff, and the share of staff with a bachelor's degree or higher. These factors are believed to reflect a firm's absorptive capacity with regard to innovation activities. First, we find that the share of management staff has a significant negative relationship with the following barriers: a lack of government policy support, financial innovation barriers, a lack of qualified innovation personnel, and a lack of innovation incentive mechanisms. We also find that the share of management staff has a positive relationship with the following barriers: a lack of innovation partners, a lack of intellectual property

protection, a lack of information on technology, and a lack of enterprise management skills. Second, we find that the share of technology staff has a negative relationship with the following barriers: a lack of government policy support, a lack of innovation partners, a lack of information on technology, a lack of qualified innovation personnel, and a lack of innovation incentive mechanisms. We also find that the share of technology staff has a positive relationship with the following barriers: a lack of intellectual property protection, a lack of enterprise management skills, financial barriers to innovation. Third, we find that the share of staff with a bachelor's degree or higher has a negative relationship with the following barriers: a lack of enterprise management skills, a lack of qualified innovation personnel, and a lack of innovation incentive mechanisms. Moreover, we also find that the share of staff with a bachelor's degree or higher has a positive relationship with the following barriers: a lack of government policy support, a lack of innovation partners, a lack of intellectual property protection, a lack of information on technology, and financial barriers to innovation.

Our results for industry sector indicators confirm that Chinese firms in the manufacturing industry and the service industry will perceive innovation barriers differently. In terms of the independent variables for industry sector, we find that manufacturing firms perceive a lack of intellectual property protection (28.45%, 1% significant), a lack of information on technology (9.31%, 5% significant), and a lack of innovation partners (7.33%, 5% significant) as the most important innovation barriers. In addition, manufacturing firms perceive a lack of enterprise management skills (-10.17%, 5% significant) as less important. On the other hand, we find that service industry firms in China perceive innovation barriers differently. In line with previous research, service firms have a significant negative relationship with most of the innovation barriers. Hölzl and Janger (2014) found that manufacturing firms perceive a greater influence of some innovation barriers than non-manufacturing firms do. Peneder (2010) also found that firms in industries with high innovation intensity generally perceive slightly more financial barriers. Comparing the coefficients of our results, we find that Chinese manufacturing firms perceive intellectual property

protection problems as the most important innovation barriers when they undertake innovation activities. Chinese service firms are less likely than manufacturing firms to perceive barriers when they undertake innovation activity. Service firms consider a lack of qualified innovation personnel to have the least important impact on innovative efforts. They regard financial barriers to innovation as the second least important innovation barrier. Interestingly, we find that a lack of intellectual property protection has a positive but insignificant effect on service firms, meaning that both manufacturing and service firms in China face intellectual property protection problems.

Our results for exporting variables confirm that exporting firms perceive a range of innovation barriers differently. When entering foreign markets, they tend to report a lack of intellectual property protection, a lack of innovation partners, and a lack of qualified innovation personnel more than other barriers. Interestingly, our results show that Chinese firms are less likely to encounter financial barriers when they export to foreign markets. In addition, exporting firms in China regard a lack of information on technology and a lack of innovation incentive mechanisms as unimportant barriers.

5.6 Robustness

Comparing them with the baseline results, we present robustness test results in Table 14. We estimate a linear probability model instead of a multivariate probit model as a robustness test. Angrist and Pischke (2008) argued that, if a researcher is interested in the mean effect, $E(Y = 1|X)$, instead of the whole distribution, the LPM with heteroskedasticity-robust standard errors is an appropriate choice. They found little difference between the marginal effects estimated with limited dependent variable models and linear probability models. In addition, Holzl and Janger (2014) claimed that ordered probit models failed to converge for a number of specifications and that, for the specifications that did converge, no substantial qualitative differences emerged

with regard to the interpretation of our results. Similar to Holzl and Janger (2014), we reduce the informational content of the dependent variable and do not divide the dependent variable into subgroups. Our robustness test results are shown in Table 14. Comparing the robustness test outcomes with the baseline results clearly shows that modifying the econometric method does not change our qualitative and quantitative results.

Table 14 Innovation Barrier Regression Results (Linear Probability Model)

This table presents the results of the analysis of Chinese firm's perception of innovation barriers obtained employing the linear probability model. The model includes eight regular innovation barriers (lack of government policy support, lack of innovation partners, lack of intellectual property protection, lack of information on technology, lack of enterprise management skill, financial barriers to innovation, lack of qualified innovation personnel, and lack of innovation incentive mechanisms). The z-stat is shown at the 10% level, the 5% level and the 1% level (denoted *,** and ***, respectively).

Dependent Variables	Lack of government policy support	Lack of innovation partners	Lack of intellectual property protection	Lack of information on technology
Firm age	-0.0004 (0.0004)	0.001** (0.0004)	0.0001 (0.0003)	-0.0007* (0.0004)
Profitability	0.019*** (0.007)	0.039*** (0.007)	0.019*** (0.005)	0.023*** (0.006)
Exporting	-0.007 (0.009)	0.033*** (0.009)	0.051*** (0.007)	0.0056 (0.008)
Firm size	0.026*** (0.008)	0.03*** (0.009)	0.022*** (0.007)	0.023*** (0.008)
Percentage of management staff	-0.0004 (0.0004)	0.0002 (0.0004)	0.0002 (0.0003)	0.0004 (0.0003)
Percentage of technology staff	-0.00001 (0.0003)	-0.0008*** (0.0003)	0.0005** (0.0002)	-0.0001 (0.0002)

Percentage of staff with bachelor's degree or above	0.0015*** (0.0002)	0.0002 (0.0002)	0.0003* (0.0002)	0.0002 (0.0002)
Innovation	0.092*** (0.009)	0.069*** (0.009)	0.097*** (0.007)	0.071*** (0.008)
Manufacturing Dummy	0.0089 (0.01)	0.021* (0.011)	0.043*** (0.008)	0.021** (0.01)
Service Dummy	-0.041*** (0.014)	-0.090*** (0.015)	0.013 (0.011)	-0.038*** (0.013)

Table 14 Innovation Barrier Regression Results (Linear Probability Model) (continued)

Dependent Variables	Lack of enterprise management skill	Financial barriers to innovation	Lack of qualified innovation personnel	Lack of innovation incentive mechanism
Firm age	-0.0002 (0.0003)	-0.0001 (0.0004)	0.001** (0.0005)	0.0007*** (0.0003)
Profitability	-0.019*** (0.005)	-0.063*** (0.007)	0.025*** (0.008)	-0.0015 (0.004)
Exporting	0.0024 (0.006)	-0.063*** (0.009)	0.044*** (0.01)	-0.011* (0.006)
Firm size	-0.006 (0.006)	0.031*** (0.009)	0.04*** (0.01)	0.009 (0.005)
Percentage of management staff	0.0002 (0.0003)	-0.001** (0.0004)	-0.0002 (0.0004)	-0.0001 (0.0002)
Percentage of technology staff	-4.6e-06 0.0002	0.0003 (0.0003)	-0.0004 (0.0003)	-0.00005 (0.0002)

Percentage of staff with bachelor's degree or above	-0.0008*** (0.0001)	0.0006*** (0.0002)	-0.0008*** (0.0002)	-0.0004*** (0.0001)
Innovation	-0.012* (0.006)	0.027*** (0.009)	0.11*** (0.01)	0.03*** (0.006)
Manufacturing Dummy	-0.016** (0.007)	-0.006 (0.01)	0.017 (0.012)	0.007 (0.007)
Service Dummy	-0.031*** (0.01)	-0.116*** (0.015)	-0.153*** (0.017)	-0.018** (0.009)

5.7 Conclusion

This project seeks to analyse the different types of factors that affect Chinese firms' perceptions of the importance of particular innovation barriers. Using more than 16,000 panel data on Chinese firms over the 2005–2010 period, we testify to the effects of several firm- and sector-level indicators on Chinese firms' perceptions of 8 innovation barriers.

First, in terms of the relationship between profitability and innovation barriers, our results show the different effects that a firm's profitability has on its perceptions of each innovation barrier. Consistent with our hypothesis, our results indicate that profitable firms do not perceive financial barriers as important constraints when they undertake innovation activities. Interestingly, profitable Chinese firms perceive more government-related innovation barriers from the external environment, such as a lack of government support and intellectual protection problems. This finding supports the more important role played by governments in developing countries in local firms' innovation activities; therefore, firms' perceptions of government-related regulation barriers will differ.

Second, in terms of the relationship between a firm's innovation involvement and innovation barriers, our results are consistent with those of previous empirical research, and we find that Chinese firms that are involved in innovation are more likely to perceive all kinds of innovation barriers. Our results suggest that a failure to hire qualified staff, a lack of intellectual property protection, and a lack of government policy support generally prevents firms from undertaking innovation activities.

Third, in terms of the relationship between the industry sector and innovation barriers, we find that each innovation barrier has significantly different effects on manufacturing firms and service firms. When they undertake innovation activities, Chinese manufacturing firms regard intellectual property protection problems as the most important innovation barriers. In addition, they undertake innovation activities,

Chinese service firms will perceive fewer barriers than manufacturing firms. Chinese service firms perceive a significant negative relationship with 7 innovation barriers, suggesting that the effects of obstacles are industry dependent. Service firms consider a lack of qualified innovation personnel to have the least important impact on innovative efforts. Compared with manufacturing firms, Chinese service firms are less likely to perceive barriers when they undertake innovation activities.

Fourth, for other control variables, our results show that younger Chinese firms have more flexibility than older firms in developing innovation incentive mechanisms and obtaining qualified innovative personnel and appropriate partnerships. In addition, larger firms perceive fewer innovation barriers, even financial barriers. These results are similar to those most existing empirical studies and confirm that the relative strength of small firms lies in their innovation flexibility.

The findings of our study provide important implications for both firm managers and government policymakers. Managers who need to overcome a lack of appropriate innovation partners and qualified personnel should focus on hiring more employees with a bachelor's degree or higher and increasing their share of technology staff. Highly educated and technologically competent staff will help firms resolve many internal innovation problems. In addition, because firms that are involved in innovation activities always perceive financial constraints, firm managers should carefully consider and balance the current capital reserves and future innovation benefits when they make decisions regarding innovation. For government policymakers, our findings suggest that exporting firms and profitable firms are less likely to perceive financial barriers; however, these firms still perceive many innovation difficulties in their external environments, such as a lack of government support, a lack of innovation partners, a lack of intellectual property protection, and a lack of qualified innovation personnel. The government should introduce more policies to incentivise innovation and construct a more supportive environment to reduce potential barriers for innovators.

For future studies, we have identified the different perception of innovation barriers between developing and developed countries in this project. Although our analysis of

Chinese firms' innovation has illustrated this difference, it only reflects the reality of one single developing country. If we will collect innovation data and employ the same methodology to analyse the innovation activities of firms in other developing countries, the results can further extend the literature in this stream of research.

6. Summary

In this thesis, we have reviewed the literature on the determinants of a firm's innovation success and the application of the IVC model in developing counties. Previous studies have indicated that the IVC is a reliable model that reflects a firm's knowledge sourcing, knowledge transformation in developed countries. We also review the literature on perceptions of innovation barriers and their effects on a firm's innovation success. Previous studies have suggested that internal and external factors will affect a firm's ranking and perceptions of specific innovation barriers. Such studies have also found that firms' innovation outputs are affected by some innovation barriers, especially financial barriers. However, it is unclear whether the IVC model and the interrelationship between a firm's perceptions of innovation barrier and its innovation behaviours are applicable in the business environment of developing countries. By analysing Chinese innovation survey data, we examine studies on the knowledge sourcing of Chinese enterprises and identify the interrelationship between different forms of sourcing in project 1. We find complementary effects between a firm's internal knowledge sourcing and other external knowledge sourcing, but we observe no substitutable relationship in China. Our results also suggest some complementarity between different forms of external knowledge sourcing. Our results show that a firm that undertakes one form of external knowledge sourcing is more likely to have other types of external knowledge sourcing relationships.

We study a firm's knowledge transformation processes in project 2. During the knowledge transformation process, our results suggest that firms are more likely to innovate successfully when their knowledge sourcing comes from internal R&D. The

establishment of a formal R&D department has a significant positive effect on a firm's product innovation success. In terms of external knowledge sourcing, we find that competitors are the most effective knowledge sources for a firm's product innovation success. The other three external knowledge sources have little impact on a firm's innovation success. In addition, we find that larger firms are more likely to have product innovation success and that government support has a significant effect on a firm's product innovation output.

We analyse different factors that affect the ranking of innovation barriers in project 3. In our analysis of the relationship between profitability and innovation barriers, the results indicate that profitable firms are more likely to perceive innovation barriers from external environment, such as a lack of government support and intellectual protection problems, instead of financial constraints. In addition, our results suggest that profitable firms are less likely to perceive innovation barriers related to management skills. In terms of the relationship between a firm's innovation involvement and innovation barriers, our results show that a failure to hire qualified staff, a lack of intellectual property protection, and a lack of government policy support are three high-ranking innovation barriers when Chinese firms undertake innovation activities. In terms of the relationship between the industry sector and innovation barriers, we find industry-dependent effects of obstacles and significantly different effects of each innovation barrier on manufacturing firms and service firms. Chinese service firms are less likely than manufacturing firms to perceive barriers when they undertake innovation activities.

To sum up the overall findings of this thesis, our research explores the linkage between firm's knowledge sourcing, innovation output, and innovation barrier perception in developing countries. We combine firm's recursive innovation activity based on the research framework of innovation value chain and innovation barrier analysis. We have provided a more comprehensive view of the differences in firms' innovation environments and innovation behaviours in developed and developing

countries. Our results reveal that, although firms' internal knowledge sourcing and other external knowledge sourcing have complementary effects, there are no substitution effects between any two knowledge sourcings in China. In terms of the knowledge transformation process, we find that in-plant R&D has the most strongly positive and significant effect on the probability of a firm's undertaking successful product innovation. Our results based on our estimate of Chinese firms' perceptions of innovation barriers indicate that profit firms are more likely to perceive government regulation barriers and market information barriers and that Chinese firms perceive government-related innovation barriers as more of a problem than other barriers.

The main implication of our findings is that they provide a practical perspective on the innovation process for both private firm managers and local government policymakers. In relation to policymakers, first, our findings indicate that government support will have a significant positive effect on firms' knowledge source absorption capacity. Our results show that government support will significantly enhance firms' knowledge sourcing from internal R&D and from universities and research institutions. Second, our findings indicate that government support will have a significant positive effect on firms' innovation success. Recently, governments have extensively implemented programmes to support firms' innovation activities. Our results show that the implementation of these kinds of policies is appropriate. Third, our findings suggest that even exporting firms and profitable firms will still perceive many innovation difficulties in their external environments, The government should introduce more policies to incentivise innovation and construct a more supportive environment to reduce potential barriers for innovators.

In relation to firm managers, first, our findings indicate that, because each knowledge source is complementary to other knowledge sources, firms should pay more attention to the competitive advantages of knowledge sourcing. In addition, if firms want to enhance their knowledge sourcing from internal R&D and their cooperation with universities and research institutions, establishing an R&D department and recruiting an R&D workforce are good starting points. Second, to achieve more innovation

success, managers should invest more resources into developing firms' internal R&D knowledge-sharing mechanisms. They should also attempt to enhance firms' absorptive capacities by recruiting talented personnel and by applying to become national technology centres and post-doctoral stations. Third, managers who need to overcome a lack of appropriate innovation partners and qualified personnel should focus on hiring more employees with bachelor's degrees or higher and increasing their share of technology staff. Highly educated and technologically competent staff will help firms resolve many internal innovation problems. In addition, because firms that are involved in innovation activities always perceive financial constraints, firm managers should carefully consider and balance current capital reserves and future innovation benefits when they make decisions regarding innovation.

Our thesis makes the following contributions to the existing literature. First, we introduce knowledge absorptive capacity to the analysis of firms' perceptions of innovation barriers and describe the linkage between knowledge sourcing, innovation output, productivity enhancement and barrier perception based on the knowledge transfer aspect. Previous studies in this field have always ignored the effect of a firm's absorptive capacity on innovation barriers. They do not include the indicators that reflect firms' knowledge storage capabilities (D'Este et al., 2012, Holzl and Janger, 2014). We believe that a firm's absorptive capacity is an underlying determinant of the overall innovation process and that it will have a long-term effect on the firm's innovation success. Our result indicates that a firm's absorptive capacity indeed has a significant effect on each step of the recursive innovation process.

Second, we highlight the effect of government support on private firms' innovation activities. Previous studies have ignored government influence on firms' innovation in developed countries (Iammarino et,al 2009, Doran and O'Leary 2012). This is mainly because, in developed countries, government plays a much less important role in private firms' innovation activities and because such support is always provided within a "small government and large market" framework (Liu and White, 2003, Eun et al. 2006). In this research, we outline the government's effect on the recursive innovation process, from knowledge sourcing, transformation, and exploitation to

innovation barriers. We find that both government innovation incentives and government-related obstacles play important roles in private firms' innovation activities.

Third, unlike previous research that focuses on the innovation process in developed countries (Doran and O'Leary 2011 in Ireland, Ganotakis and Love 2012 in the UK, Love et al. 2012 in Northern Ireland, Iammarino et,al 2009 in Italy, D'Este et al., 2012 in the UK), our research extends the use of the recursive innovation process analysis method to one of the largest export-oriented developing countries. Thus, we discover which determinants of the innovation process are universal for firms in both developed and developing countries. We also understand the potential differences in firm's internal innovation capacities and their external innovation environments in developed and developing countries.

With regard to further research, we have, in this thesis, identified the differences in firm's knowledge sourcing, knowledge transformation and perception of innovation barriers between developing and developed countries. Although our analysis of Chinese firms' innovation has illustrated this difference, it only reflects the reality of one single developing country. If we were to collect innovation data and employ the same methodology to analyse the innovation activities of firms in other developing countries, the results can further extend the literature in this stream of research. In addition, since our database derive from government-lead surveys and may cause bias from potential artificial manipulation, if we were to collect innovation data from other privated-lead survey in China, it would be possible to make our result more representative and better supported.

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